DOCUMENT RESUME

ED 277 538 SE 047 619

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TITLE The Science and Technology Resources of West Germany: A Comparison with the United States. Special Report.
INSTITUTION National Science Foundation, Washington, D.C. Div. of Science Resources Studies.
REPORT NO NSF-86-310
PUB DATE Mar 86
NOTE 59p.
AVAILABLE FROM National Science Foundation, Washington, D.C. 20550 (Single copy, free).
PUB TYPE Reports - Descriptive (141)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS *College Science; *Comparative Analysis; Economic Development; Financial Support; Foreign Countries; Government Publications; Higher Education; Institutional Research; International Relations; *International Trade; *Investment; Research Administration; Research and Development; Science and Society; Science Education; Scientific Research; *Technological Advancement; Technology; Trend Analysis
IDENTIFIERS *West Germany

ABSTRACT

West Germany has traditionally excelled in science and technology. During the past 20 years, it has increased its expenditures and personnel for research and development to the extent that it has now reached a level of research and development investment that is comparable to that of the United States. This document profiles West Germany's scientific and technological investments and outputs since 1970, and compares them with those of the United States. The introduction explains the responsibilities for scientific research and development that exist within the federal and state levels of the West German government. The major portion of the report then compares West Germany and the United States with regard to: (1) national research and development patterns; (2) government efforts in research and development; (3) special West German science and technology organizations; (4) industrial research and development; (5) research and development in higher education; and (6) science and technology outputs and impacts. The appendices include technical notes and statistical tables. (TW)

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Suggested Citation

The Science and Technology Resources of West Germany: A Comparison with the United States (NSF 86-310)(Washington, D.C., 1986).

foreword

The Division of Science Resources Studies of the National Science Foundation has initiated efforts to obtain more recent and detailed quantitative information on foreign science and technology (S/T) capabilities and activities—principally in the large research and development (R&D)-performing industrialized nations. This report presents a statistical profile of West Germany's S/T effort since 1970 and compares it with that of the United States. R&D trends in West Germany at the national level as well as for individual sectors are presented, and data on S/T outputs are discussed.

William L. Stewart
Director, Division of
Science Resources Studies
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March 1986

acknowledgments

This report was prepared by Jennifer Sue Bond, Senior Staff Associate for International Science and Technology Studies. Supervision, review, and guidance were provided by Charles E. Falk, former Director, and William L. Stewart, Director, Division of Science Resources Studies. Efforts are constantly underway to collect the most recent data. Such new data or additional detail may be obtained from the author:

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introduction

West Germany has traditionally excelled in science and technology. During the last 20 years, it has increased its expenditures and personnel for research and development to the extent that it has now reached a level of research and development (R&D) investment that is comparable to that of the United States in terms of size of the economies. This report profiles West Germany's scientific and technological (S/T) investments and outputs since 1970 and compares them with those of the United States.

In West Germany, responsibility for science and for research and development is divided between the Federal and State Governments. School and university affairs are principally the responsibility of the State which provides support for faculty salaries and operating expenses as well as basic laboratory equipment. Under the Basic Law adopted by the Constitutional Assembly in 1949, the Federal Government was given concurrent legislative powers with regard to the promotion of scientific research. In 1969, changes in the Basic Law gave the Federal Government wider powers, enabling it to participate in the planning and financing of higher education and to assist in constructing and expanding new universities and clinics. The Federal and State Governments also share joint responsibility for funding certain research institutes and projects.[1]

Because of these joint responsibilities, data on West German Government research and development reflect the contributions of both the Federal and State Governments. In the United States, the Federal Government has assumed the primary role of funding research and development and thus U.S. Government R&D expenditures presented here are separately budgeted Federal expenditures. State contributions to academic research and development in the United States are reported by universities and colleges as their own funds.

A discontinuity in the West German R&D data was caused by the introduction in 1978 of a major Federal R&D promotion program for small- and medium-sized firms. Under this program, the Government supports 40 to 50 percent of the salaries of R&D personnel in small companies (under 500 employees) and up to 45 percent of new or additional R&D personnel in medium-sized firms (500-5,000 employees).[2] This program increased actual R&D investments, and also led to an extension of coverage of newly identified small- and medium-sized firms in the survey of industrial R&D efforts. Therefore, the rate of growth in West German R&D expenditures and number of R&D personnel between 1977 and 1979 was somewhat exaggerated. Nevertheless, there would still have been growth in West German R&D investments. The average annual growth rate of industrial R&D expenditures from 1977 to 1979 is estimated to have been 11 percent in constant dollars without the inclusion of these small- and medium-sized firms, and the average increase of scientists and engineers engaged in research and development would still have been 11 percent.[3]

The latest actual R&D expenditure data available for West Germany in many cases are for 1981. The data on 1982 and 1983 are preliminary figures. Some budgetary figures for 1985, as well as Federal plans for R&D expenditures in 1987, are presented for West Germany. Data are unavailable for a few of the years, and in those cases, estimates by the National Science Foundation (NSF) have been provided and are noted as such in the tables in the appendix. NSF estimates have been based on preliminary national data for 1983-85 in the ratio of research and development to the gross national product (R&D/GNP) and in the nondefense R&D/GNP ratio. Data are available for the United States that are more recent than those shown in this report, but because the focus is on West Germany rather than the United States, U.S. data are shown only through the latest year for which actual West German expenditure data are available.

[1]Hildegard and Reinhold Geimer, *Research Organization and Science Promotion in the Federal Republic of Germany* (Munich, West Germany: K. G. Saur, 1981).

[2]Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT). This program has changed slightly over the years. See page 21 for more details.

[3]Organisation for Economic Co-operation and Development (OECD).

highlights

national r&d patterns

- Although West German expenditures for research and development are only one-fifth those of the United States, the ratio of these expenditures to the GNP has been similar for each of the two countries since the late seventies. Estimates for 1985 indicate that the United States has increased its R&D/GNP ratio to 2.7 percent compared with 2.6 percent in West Germany.
- In constant-dollar terms, R&D expenditures in West Germany and in the United States increased 75 percent and 63 percent, respectively, from 1970 to 1985. Since 1975, however, R&D expenditures have grown more rapidly in the United States.
- West Germany has a higher ratio of nondefense R&D expenditures to GNP than does the United States. In 1985, the West German ratio was estimated to be 2.5 percent compared with 1.9 percent for the United States.
- A high proportion of West German R&D expenditures is devoted to basic research—22 percent in 1981. In the United States, basic research represents about 13 percent of total R&D expenditures. The lower U.S. share is influenced by large development expenditures associated with defense needs.
- In both West Germany and the United States, 60 percent of basic research is performed in the higher education sector and almost one-fifth in the industrial sector.
- In the early eighties there was about the same concentration of natural scientists and engineers in the labor force in both countries. Estimates for 1984 show almost 5 West German scientists and engineers engaged in research and development for every 1,000 persons in the labor force compared with more than 6 in the United States.

government research and development

- The Government share of R&D funding has declined in both countries. In 1973, at least half of each Nation's R&D funds was supplied by the public sector. By 1983, Government was the source of only 41 percent of the West German national R&D funding effort, compared with 47 percent in the United States. Estimates for 1985 indicate that these shares have remained steady.
- R&D funding is nevertheless seen as an important priority for both the Governments of West Germany and the United States. West German Federal budget data show a 16-percent increase for research and development between 1983 and 1985, compared with a 28-percent increase in the United States.
- About two-thirds of the U.S. Government funds for research and development were invested in defense projects in 1984; West Germany's investment for defense research and development represented only 10 percent of Government R&D funds in 1983, but increased to 12 percent in 1985.
- Energy represented a higher proportion (15 percent) of Government R&D funds in West Germany than in the United States (6 percent) in 1984. But the West German Federal Government plans to decrease funding in this area through 1987 and estimates for 1985 show that energy decreased to 13 percent of total Government R&D spending.
- In 1983, the West German Federal Government budgeted $36.4 million for research and development in biotechnology, and plans to increase expenditures by about 6 percent per year through 1987. By comparison, one estimate of U.S. Government expenditures in biotechnology in fiscal years 1982 and 1983 is over $522 million.

- In 1983, industrial development was allotted 12 percent of Government R&D funds in West Germany, compared with only 0.3 percent in the United States. Although it is currently a small program, West German Federal funding of manufacturing production technology is scheduled for average annual increases of 37 percent through 1987.

special west german s/t organizations

- Although the Max-Planck Society has considerable influence and is important in the West German basic research effort, its budget represents only about 2 percent of the national R&D expenditures in West Germany. In 1983, current R&D funds designated for Max-Planck Institutes were about $375 million. Over 60 percent of these funds were allocated to natural science fields.
- The Fraunhofer Society is an important performer of applied research and development. In 1985, it is estimated that 60 percent of this Society's finances came from contract work—both for industry and government. It is instrumental in doing research in the key technology areas identified by the Federal Ministry for Research and Technology and also has six institutes devoted to defense research and supported by the Federal Ministry of Defense.
- West Germany has 13 large-scale national laboratories, many of which are involved in high-energy physics and nuclear research. In 1983 their budgets totaled $1.6 billion, about 90 percent of which was financed by the Federal Ministry for Research and Technology.
- The German Research Society is not an R&D-performer organization; rather it distributes R&D funds primarily to the higher education sector. Almost all of its funds are from public sources. In 1984, its budget was about $440 million, with Federal sources providing 58 percent, and State governments giving 41 percent. About a third of its resources went to life sciences, a fourth to physical science and mathematics, and more than a fifth to engineering.

industrial research and development

- About 70 percent of all research and development was performed in the industrial sector in both West Germany and the United States in 1983.
- Throughout most of the 1970's, industrial R&D expenditures increased much more rapidly in West Germany than in the United States. West German industrial R&D growth has slowed since—rising only 10 percent in constant dollars during 1979-83 compared with 25 percent in the United States. In 1983, U.S. industrial R&D funds were five times those of West Germany.
- Industrial R&D expenditures were twice as concentrated in the chemical and allied products industries in West Germany in 1981 as they were in the United States.
- The R&D-to-sales ratio for all industries combined was slightly lower in West Germany—2.8 percent in 1981—compared with 3.1 percent in the United States. Using this measure, the aerospace industry is the most R&D-intensive in both countries.
- Industrial R&D scientists and engineers are most heavily concentrated in the electrical equipment industry. In West Germany, 38 percent of all such scientists and engineers were employed in this industry compared with 22 percent in the United States.

higher education

- West Germany invests about the same proportion of its R&D expenditures in the higher education sector (16 percent in 1983) as does the United States (13 percent). Both countries concentrate their R&D resources in the natural sciences.[4]
- The number of first university diplomas awarded by West Germany in the natural science fields increased 65 percent from 5,400 in 1973 to 8,900 in 1983. Over the same period, the number of U.S. bachelor degrees in natural sciences increased only 11 percent. The United States, however, grants over three times the number of natural science degrees relative to its population than does West Germany.
- First university diplomas awarded in engineering increased over 70 percent in West Germany during the 1973-83 period, reaching a total of 7,700. In 1983, 12 to 13 out of every 100,000 people in West Germany received a university engineering degree compared with 31 in the United States. If one were to include fachhochschule engineers whose training at these technical schools is shorter and more specialized, however, West Germany's proportion of engineering degrees per 100,000 population would be 37—higher than that of the United States.
- West Germany has increased its doctoral production in natural science and engineering (S/E) fields, and in 1983 graduated a higher proportion of doctorates relative to the size of its population in both of these fields than did the United States.
- In West Germany, women receive a relatively high proportion of bachelor level degrees in natural sciences (30 percent in 1982) and a relatively low proportion of degrees in engineering (7 percent). U.S. trends are similar, but women represent a higher percentage of the recipients in both fields.

[4]Includes physical, biological, and mathematical sciences.

s/t outputs and impacts

- In 1982, West German scientists and engineers authored 6.5 percent of the articles in a set of the world's influential S/T journals. This proportion of scientific literature is twice as large as West Germany's share of the industrialized world's researchers. The highest West German share of such S/T literature was in the field of physics (6.8 percent), followed by engineering and technology, and mathematics (both 6.6 percent). Between 1981 and 1982, the West German share increased somewhat in physics and biomedical research.
- There were a number of subfields in 1982 in which West German articles represented at least 10 percent of the world's S/T literature: Applied chemistry (15 percent); nuclear technology (14 percent); orthopedics (13 percent); obstetrics/gynecology (13 percent); and microscopy (12 percent); metals and metallurgy, materials science, and nuclear and particle physics (each 10 percent).
- Patent applications are frequently used as indicators of inventiveness. Domestic patent applications decreased in both West Germany and the United States in the seventies. Recent data show a more optimistic picture; from 1981 to 1984, domestic patent applications increased 9 percent in West Germany compared with only a 1-percent decline in the United States.
- The number of U.S. patents granted to West German inventors rose more than 40 percent from 1970 to 1984. Over 60 percent of all U.S. patents granted to West German inventors are in machinery and chemical and allied products technologies.
- Some of the product groups in which West German inventors were granted the highest proportion of U.S. patents of any foreign country were railroad equipment, special industrial machinery, industrial organic chemistry, agricultural chemicals, ordnance, and missiles and space vehicles.
- West Germany has a negative balance of trade in technology-intensive products with the United States. In 1970, this deficit was only $0.5 billion, but by 1981, it reached $2.8 billion. Since then there has been an improvement in the West German trade balance with the United States which registered -$1.5 million in 1984. In 1984, West Germany's deficit with Japan ($2.4 billion) was greater than its deficit with the United States. West Germany maintains a positive balance of technology-intensive trade with Italy, France, and the United Kingdom and registered a positive world balance of trade in these products of $10.6 billion in 1984.
- Between 1970 and 1984, both the West German and U.S. world export shares declined in many of the technology-intensive product groups. West Germany increased its export share only in aircraft and parts—from 3.4 percent in 1970 to 15.2 percent in 1984. Its export share was highest in plastics and synthetic materials and this share has remained steady at about 21 percent.

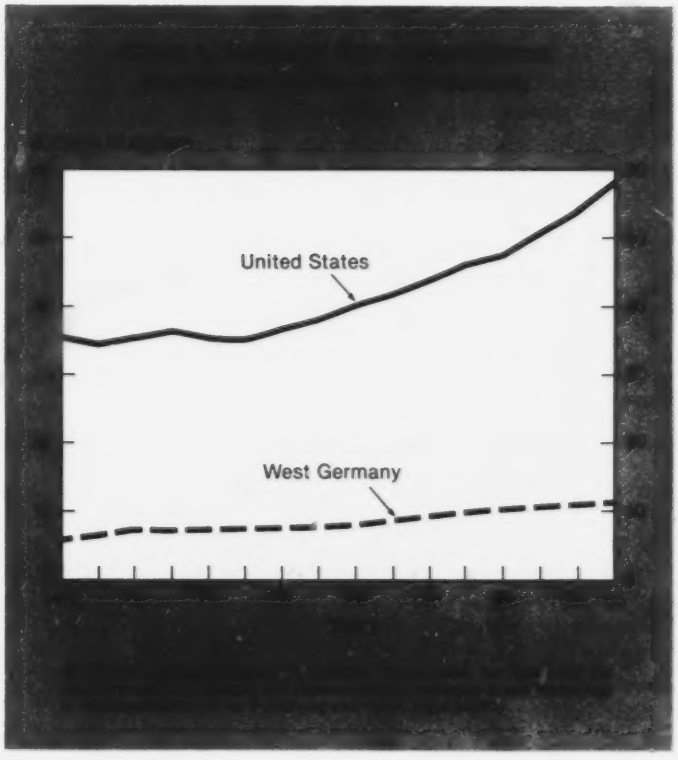
national r&d patterns

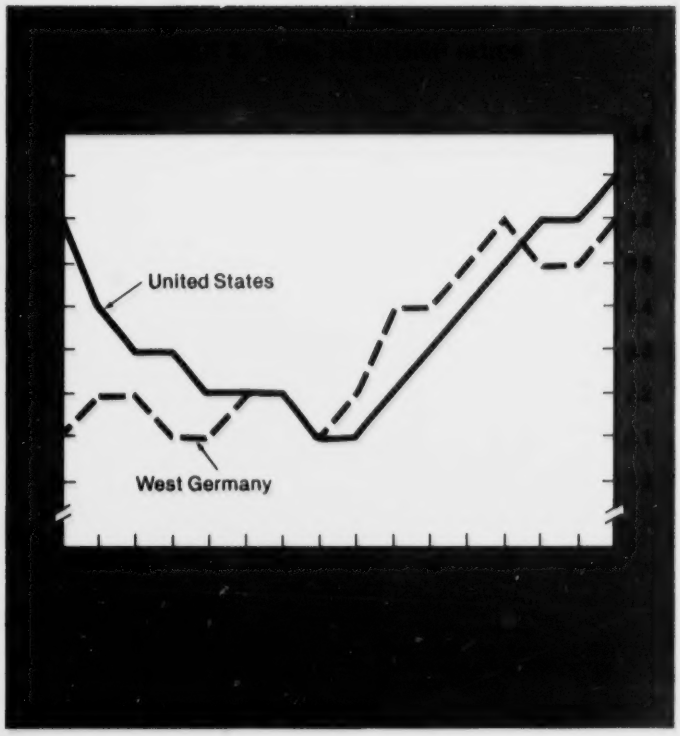
total r&d expenditures

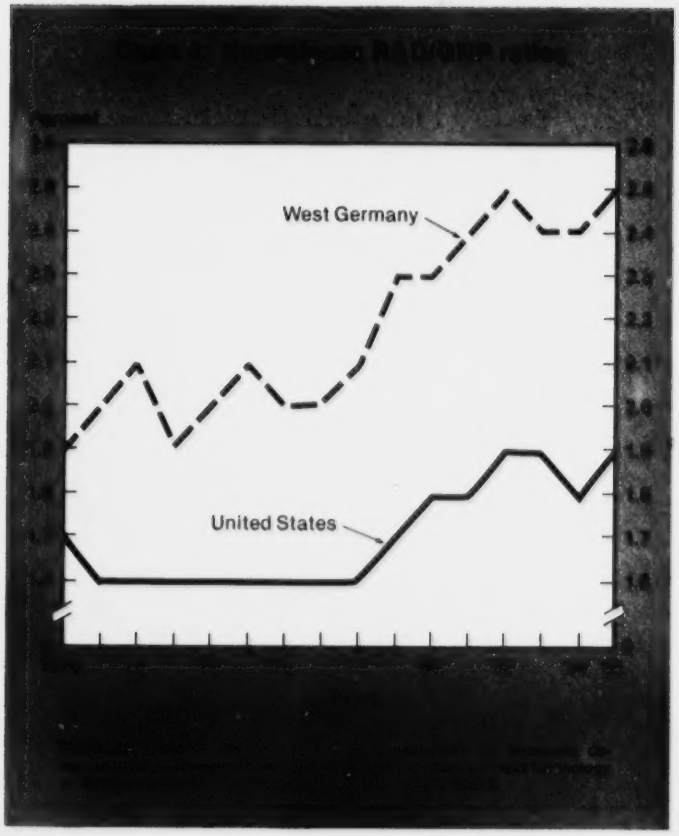
Between 1970 and 1985, R&D expenditures in West Germany increased 75 percent in constant-dollar terms (chart 1). Over the same period, U.S. investments in research and development rose 63 percent in constant dollars. Since 1975, however, R&D expenditures have grown more rapidly in the United States. In 1985, West Germany invested over DM47 billion in research and development which is the equivalent of 11.1 billion in constant (1975) dollars, and the United States invested 58.2 billion in constant dollars.

The United States invests much more in research and development in absolute terms than West Germany, but relative to the size of its economy, the West German R&D investment is fairly comparable to that of the United States. The West German R&D/GNP ratio increased throughout the late seventies and from 1978 to 1982 actually surpassed the U.S. ratio (chart 2). Estimates for 1985 indicate that the United States increased its R&D/GNP ratio to 2.7 percent compared with 2.6 percent in West Germany.

West Germany has a higher ratio of nondefense R&D expenditures to GNP than does the United States. West Germany has generally increased its investment in nondefense research and development at a pace faster than its economic growth (chart 3). Between 1977 and 1983, nondefense R&D expenditures grew almost 70 percent in West Germany compared with a 40-percent increase in GNP. In 1983, the West German ratio reached 2.4 percent compared with a ratio of 1.9 percent for the United States. From 1982 to 1983, there was no growth in the nondefense ratios in either



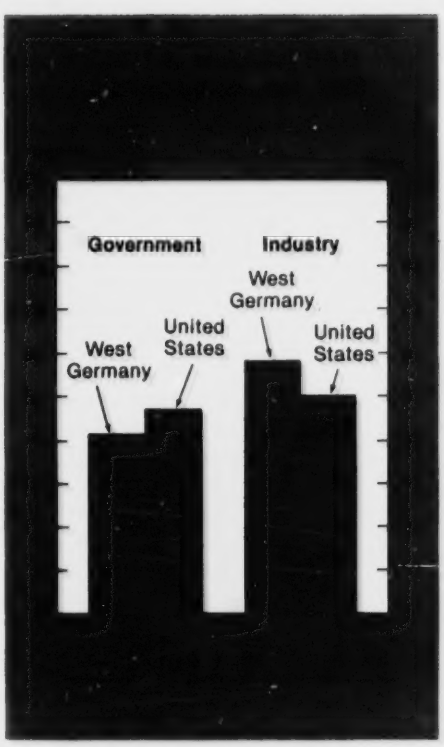




country. In West Germany both total and nondefense R&D expenditures increased, but not at a faster rate than the economy. In the United States, total R&D expenditures continued to increase faster than the GNP, but defense research and development claimed an increased proportion of the total, resulting in a slight decrease in the ratio in 1984. In 1985, the West German ratio was estimated to be 2.5 percent compared with 1.9 percent for the United States.

r&d expenditures by source

Government funds increased 20 percent in West Germany and 22 percent in the United States in real terms between 1973 and 1983, reaching a 1975 constant dollar investment level of 4.3 billion in West Germany and 23.3 billion in the United States. The Government share of R&D funding has declined in both countries. In 1973 at least half of each Nation's R&D funds was supplied by the public sector. By 1983, Government was the source of only 41 percent of the West German national R&D funding effort compared with 47 percent in the United States (chart 4).



Industry has taken an increasingly important role as a source of R&D funds in both West Germany and the United States. In 1973 West German industry provided 49 percent of all R&D funds, and by 1983, this share had increased to 58 percent. The U.S. industrial proportion of national R&D funds also grew, from 43 percent in 1973 to 50 percent in 1983.

research and development by character of work

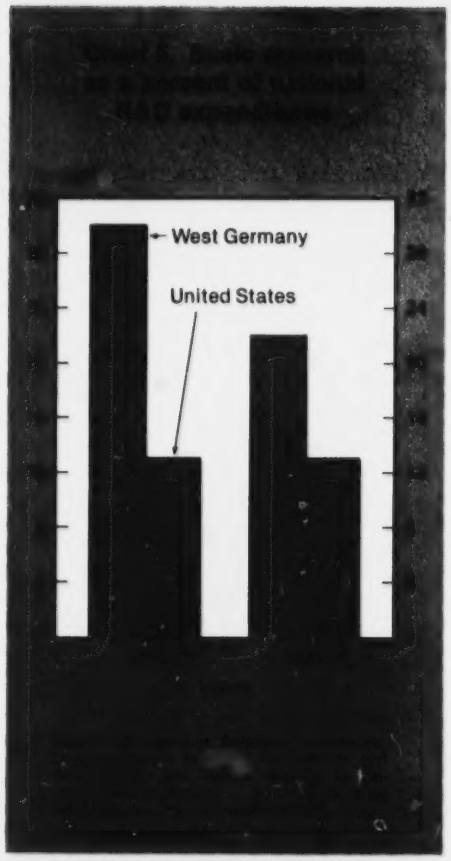
Categorizing R&D expenditures as basic or applied research or as development is a difficult and to some extent a subjective task, and thus the resulting data are not as reliable as national totals.

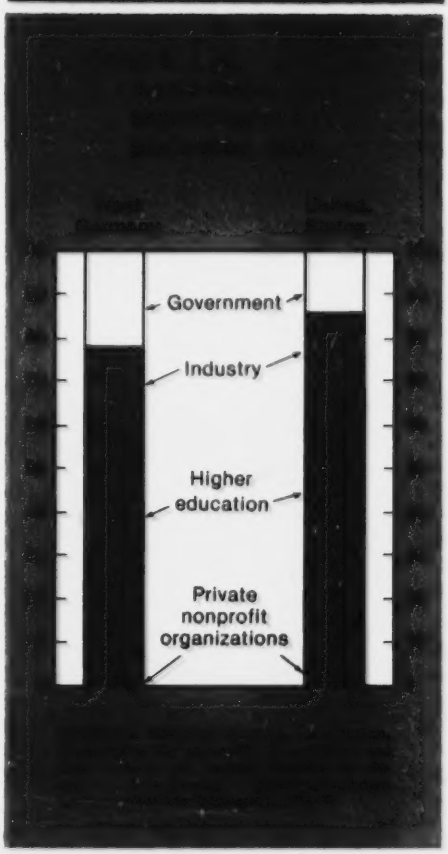
The categories for which data are presented here are in accordance with the Organisation for Economic Co-operation and Development (OECD) definitions, but it is recommended that the reader give primary consideration to overall trends and major changes rather than to detailed differences.

basic research

A high proportion of West German R&D expenditures is devoted to basic research. In 1981, basic research expenditures represented 22 percent of all current R&D expenditures in West Germany. These expenditures had diminished substantially after 1973 when the basic research share was 30 percent (chart 5). During the same period in the United States the basic research proportion remained constant at about 13 percent. The U.S. basic research share is heavily influenced by the substantial amount of research and development allocated to defense. For instance, the U.S. Federal R&D budget authority for defense activities in 1981 shows that 85 percent was directed to development compared with only 3 percent for basic research. By contrast, U.S. Federal R&D budget authority for nondefense activities was divided more evenly, with 37 percent devoted to development, 33 percent to applied research, and 29 percent to basic research.[5]

Both the Government and industry sectors of West Germany have increased their responsibilities concerning the performance of basic research. Some of the increase in industrial basic research is undoubtedly due to an increase in scope of coverage of the industrial sector. According to expenditure data, 70 percent of West German basic research was performed in the higher education sector in 1973, but by 1981 this share was 60 percent (chart 6). More than one-fifth of West German basic research was conducted in the public sector.[6] Industry spent 18 percent of all basic research funds—the same percentage as in the United States.





applied research and development

Applied research expenditures cannot be separately identified from development expenditures in West Germany. Together, these two categories constituted almost four-fifths of R&D expenditures in 1981, up from 70 percent in 1973 (chart 7). In the United States, applied research and development expenditures constituted 87 percent of all research and development in both years, with development expenditures alone accounting for 64 percent in 1981.

[5]National Science Foundation, *Federal R&D Funding: The 1975-85 Decade* (Washington, D.C., March 1984), pp. 18-20.

[6]Current R&D expenditures for the Max-Planck Institutes are all classified as basic research and are allocated to the Government sector.

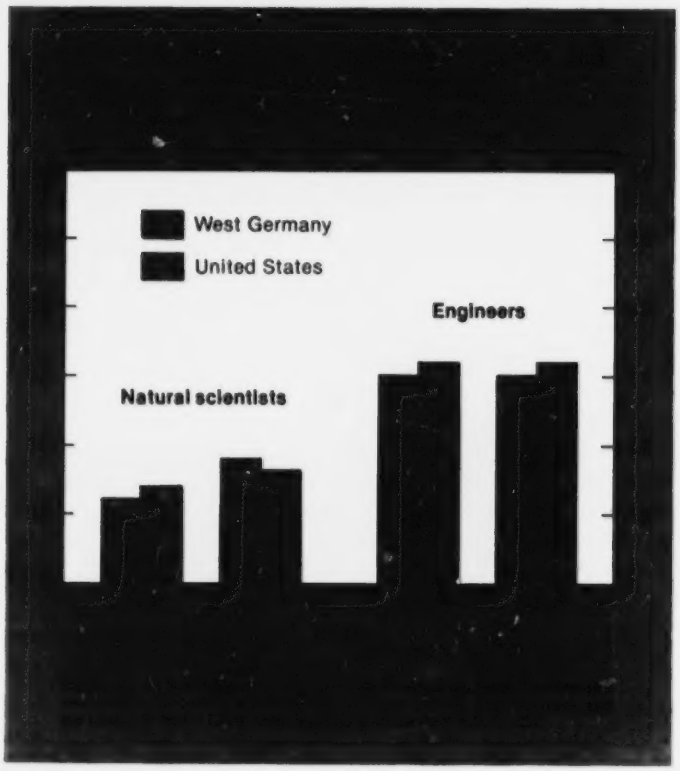
scientists and engineers

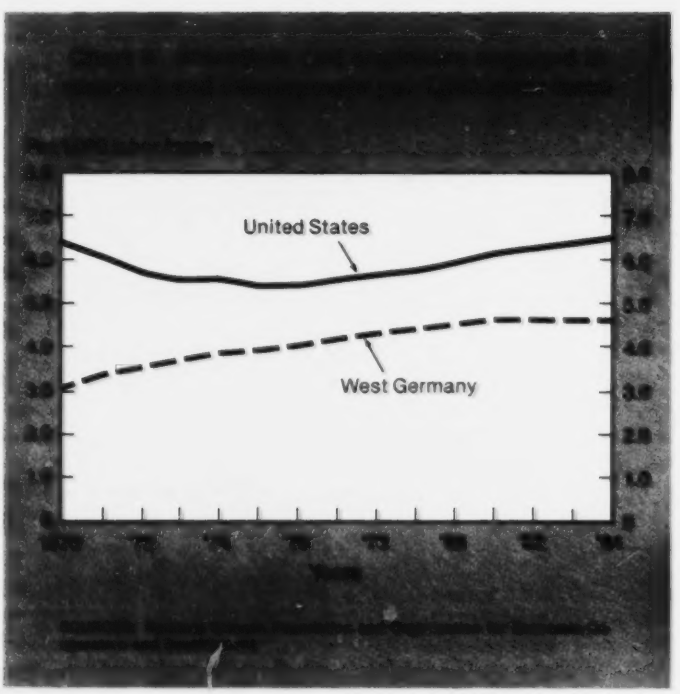
stock of natural scientists and engineers

Scientists and engineers are involved in a variety of activities, and their number is therefore a good indicator of a country's scientific and technological capability. In 1980, there were 231 thousand natural scientists and 390 thousand engineers in West Germany compared with 870 thousand natural scientists and 1.7 million engineers in the United States. Although the United States has a much larger number of scientists and engineers, the two countries have a comparable level of scientists and engineers in terms of the size of their economies. The West German ratio of natural scientists and engineers per 10,000 labor force increased from 0.6 percent in 1970 to 0.9 percent in 1980, reaching and surpassing slightly the U.S. ratio of 0.8 percent (chart 8). This was due largely, however, to changes in the general labor force. Over the decade the number of natural scientists increased over 40 percent in both countries: the U.S. labor force expanded by 27 percent and the West German labor force experienced a slight decrease. The stock of West German engineers actually declined 6 percent from 1970 to 1980. The concentration of engineers in the labor force, however, remained the same in both countries—1.5 percent for West Germany and 1.6 percent for the United States.

r&d scientists and engineers

After 1970, the number of West German R&D scientists and engineers increased 58 percent, reaching an estimated 130 thousand in 1984. In the United States the number of these researchers actually decreased in the early seventies before increasing 40 percent to a level of about 751 thousand in 1984. The West German concentration of R&D scientists and engineers in the labor force steadily increased over the period, narrowing the gap with the U.S. ratio (chart 9). In 1970 the U.S. ratio (6.4) was twice that of the West German (3.1), but by 1984 they were more comparable; there were almost 5 West German scientists and engi-





neers working on research and development per 1,000 persons in the labor force compared with more than 6 in the United States.

Part of this trend can be explained by the fact that from 1970 to 1980 the number of S/E-degree recipients in West Germany increased substantially and the number of U.S. doctoral degrees dropped 30 percent in engineering and 10 percent in the natural science fields.[7] It should also be noted that many of the engineering doctorates granted in the United States during this period were to non-citizens. By the early 1980's, foreign students represented about half of all the engineering doctoral recipients.[8]

[7]Joseph Mintzes and William Tash, *Comparison of Scientific and Technical Personnel Trends in the United States, France, West Germany, and the United States Since 1970* (NSF 84-335) (Washington, D.C.: National Science Foundation, 1985).

[8]National Science Foundation, *Science and Engineering Doctorates: 1960-82* (NSF 83-328)(Washington, D.C., 1983).

government research and development

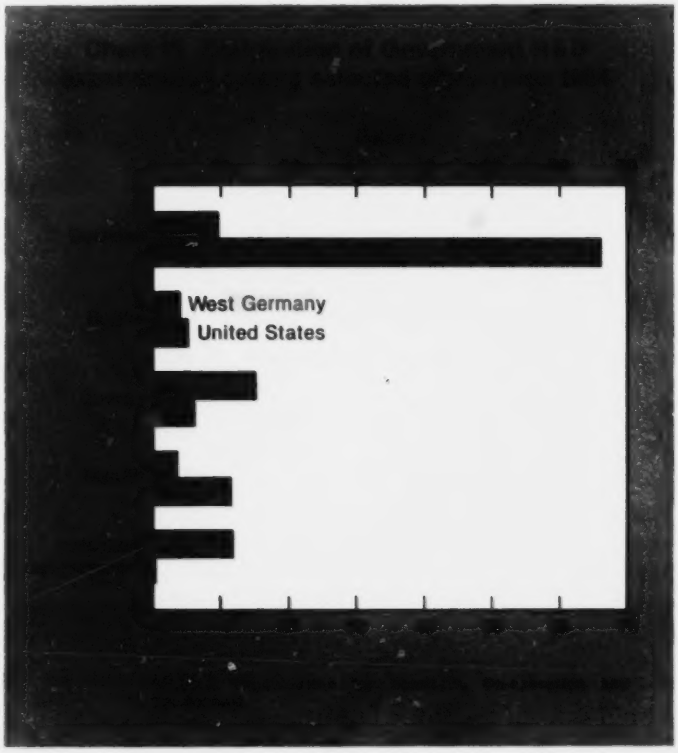
Government was the source of 41 percent of the West German national R&D effort in 1983, compared with 47 percent in the United States. In (1975) constant-dollar terms, this represented an investment of $4.3 billion for West Germany and $23.3 billion for the United States. Although West German Government funds increased about 20 percent in real terms from 1973 to 1983, the Government share of funding declined in both West Germany and the United States. In 1973, at least half of each Nation's R&D funds was supplied by the public sector, but by 1983 industry was the dominant R&D investor in both countries, supplying 58 percent of total West German R&D funds and 50 percent of U.S. funds.

Examination of 1981-83 changes in R&D funding by source shows that West German Government R&D support increased only 2.2 percent in real terms compared with a 9.0-percent increase in U.S. Government support. The slowdown in West German Government funding may reflect the Christian Democratic administration's effort to improve the investment climate by using indirect mechanisms more than direct funding of industrial research. R&D funding by the Federal Government is nevertheless increasing in both countries. West German Federal budget data show a 16-percent increase (in current terms) for research and development between 1983 and 1985 compared with 28 percent in the United States. It is estimated that both Governments provided about the same share of national R&D expenditures in 1985 as in 1983—about 40 percent in West Germany and 47 percent in the United States.[9]

In 1985, the Federal Ministry for Research and Technology sponsored 55 percent of all Federal R&D funds. The Ministry of Defense increased its role in Federal R&D funding from 16 percent in 1983 to 19 percent in 1985. (Table B-10 presents a distribution of the R&D budget by agency.)

Analysis of total Government R&D expenditures by objective shows that West German R&D priorities are quite different from those of the United States. In 1984, the West German Government expended 12 percent of its R&D funds on industrial development whereas the United States expended only 0.2 percent on that objective (chart 10). West Germany also expended considerably more

[9]Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT), *Statistische Informationen*, December 1985, and unpublished data. (Bonn, West Germany).



of its funds on energy research and development (15 percent) than did the United States (6 percent). The two countries invested about the same proportion in space research and development, but there was a major difference in their R&D expenditures for defense purposes: the U.S. Government expended about two-thirds of its funds for research and development on defense projects, whereas West Germany's investment for that objective was only about 10 percent in 1984.

Estimates for 1985 indicate that West German defense research and development has increased to 12 percent of total Government R&D funding compared with 68 percent for the United States. The proportion of Government R&D funds devoted to energy has decreased in both countries; in 1985 it was estimated to be 13 percent in West Germany and 5 percent in the United States.[10]

West German Government R&D expenditures consist of both Federal and State funds. In 1983, the Federal Government was responsible for 60 percent of total Government R&D funds. By law, the States fund almost all of the current and half of the capital expenditures for universities. The foregoing discussion of Government R&D objectives is thus influenced by the large proportion of West German Government funds allocated to general university research which is largely nonoriented.

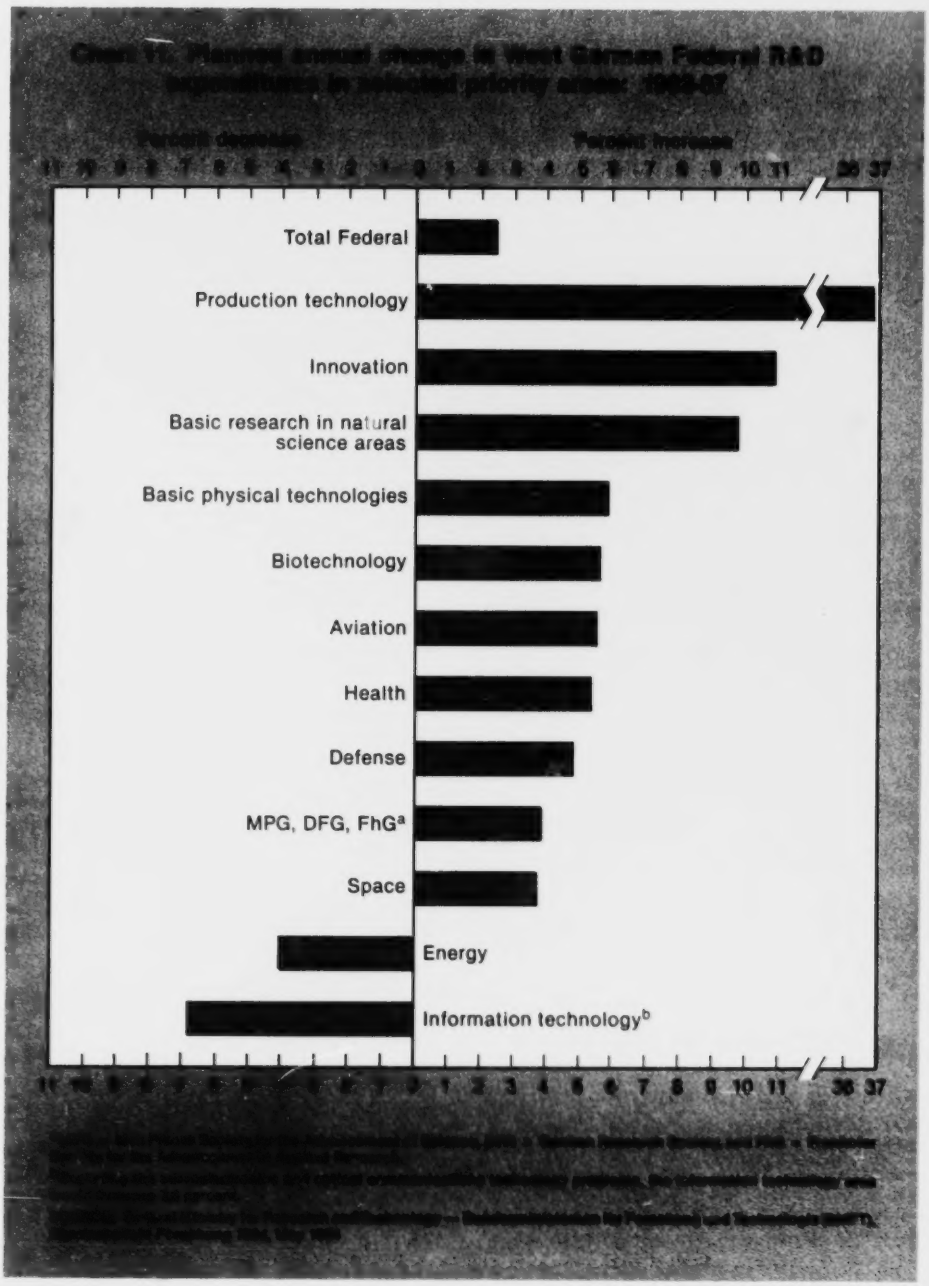
If one looks solely at Federal R&D funding in West Germany, the priority areas shift somewhat. More than one-fifth of all Federal R&D funds were invested in energy areas in 1983 and about 15 percent for defense. Funding for the Max-Planck Society for the Advancement of Science, the German Research Society, and the Fraunhofer Society for the Advancement of Research, as well as funding for basic research in the natural sciences constituted more than 14 percent of the Federal R&D budget in 1983 (table B-13).

[10]*Ibid.* and National Science Foundation, *Federal R&D Funding by Budget Function: Fiscal Years 1984-86* (NSF 85-319)(Washington, D.C., 1985).

For the first time, the Federal Ministry for Research and Technology published the long-term financial plan accepted by the Federal Government in June 1983 which details Federal R&D spending plans through 1987. This plan shows that the West German Government is continuing to promote research and development, but at a reduced pace. The average annual growth rate in Federal R&D expenditures was 7.4 percent from 1975 to 1979. It slowed to 4.7 percent from 1979 to 1983 and is expected to decrease to only 2.4 percent during the period 1983-87.[11]

Chart 11 shows the average annual percent changes in selected priority areas planned by the West German Federal Government for the period 1983-87. Promotion of innovation and basic research in selected areas of natural

[11]Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT), *Bundesbericht Forschung 1984*. (Bonn, West Germany, 1984).



sciences are among the priorities that already receive a substantial portion of the Federal R&D budget. They are scheduled to increase an additional 10 percent per year through 1987. Federal funding for manufacturing production technology will experience the largest growth—an average of 36.8 percent per year. It is a small program (about 14 million current dollars in 1983), however, and will represent only 1 percent of the total Federal R&D budget in 1987. Federal funds for biotechnology research and development are scheduled for a 5.6 percent average annual growth. In 1983, the West German Federal Government designated $36.4 million for research and development in biotechnology. (For comparative purposes, one estimate of U.S. Government expenditures in biotechnology in fiscal years 1982 and 1983 is over $522 million.)[12] Defense research and development will grow faster than the total budget and will therefore increase its percentage of the Federal R&D budget from 15 percent in 1983 to 17 percent in 1987. Energy research and development received the largest amount of Federal funds ($895 million) in 1983, but this is one area for which the Federal Government plans to reduce funding in the coming years.

Information technologies are scheduled for average annual cuts in Federal R&D expenditures of 6.8 percent, but most of the cuts are a result of the phasing out of the special program for microelectronics and optical communications technologies. The special program of the Federal Ministry for Research and Technology to promote product development in the manufacturing industry, as well as to procure research computers, ended in fiscal year 1981. Excluding this special program, research and development in other information technologies are scheduled for an average annual increase of 3.6 percent. The West German Government is still concerned about the international competitiveness of its industry, particularly in the area of integrated circuits, but has moved away from the approach of concentrated direct funding of product development. A more comprehensive plan for promoting the development of microelectronics and information and communications technologies, which calls for overlapping ministerial responsibilities in a variety of areas, was announced by the Federal Government in May 1983.[13]

In 1985, Federal funding for research and development in information technology was held constant. This area nevertheless received a greater share of funds than some other key technology areas such as biotechnology and materials research, as is evident in table 1. The funding for production technology increased substantially, and when this category is considered together with information technology, the combined funds represented 5 percent of the Federal R&D budget and constituted a 12-percent increase in 1985. Aviation research and development received a much greater increase in funding than previously planned. These key technologies represented 16 percent of the West German Federal budget for research and development in 1985.

[12]*Commercial Biotechnology: An International Assessment* (Washington, D.C.: Office of Technology Assessment, OTA-BA-218, 1984).

[13]Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT), *Bundesbericht, op. cit.*

Table 1. West German Federal R&D budget for 1985, for key technology areas

Key technology area	Millions of deutsche marks	Percent change 1984-85	Percent of budget
Information production	658.1	12.1	5.0
Information technology	512.9	.2	3.9
Production technology	145.2	93.1	1.1
Biotechnology	149.5	14.3	1.1
Materials group	335.5	4.4	2.6
Materials research	198.5	17.9	1.5
Physical technology	122.3	−10.8	.9
Chemical processes	14.7	−7.5	.1
Aviation research and technology	734.5	71.3	5.6
Marine and polar technology	236.2	5.4	1.8
Marine research	83.9	13.4	.6
Marine technology	87.9	9.6	.7
Polar research	64.4	−7.7	.5

NOTE: In 1985, a dollar is estimated to be equivalent to about 2 West German deutsche marks using OECD purchasing power parity exchange rates.

SOURCE: Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT), *Statistische Informationen*, Referat 133, December 1985

special west german s/t organizations

Special organizations are important in the performance of research and development, the financing or distribution of R&D funds, and in the coordination and evaluation of R&D activities in West Germany. Although many of these organizations are considered legally to be independent nonprofit institutions, this report follows the OECD guidelines in categorizing these institutions' R&D expenditures by sector of performance and source of funds. In general, the sector that largely controls a nonprofit organization, or that is served by a nonprofit organization, is the one to which the organization is assigned. Therefore, if a nonprofit organization's aim is mainly to serve Government, or if it is financed or controlled mainly by Government, it is considered as having performed research in the public sector. The Max-Planck Institutes and the large national laboratories are examples of this category. If the nonprofit organization renders services mainly to enterprises, such as in the case of the Confederation of Industrial Research Associations, the research and development performed is considered to be in the industrial sector and the funds received by the organization from the Government are credited to the Government when discusssing R&D expenditures by source of funds.

The following chapter describes some of the most important independent organizations in the West German S/T system and discusses their objectives, research programs, and resources. It is not intended to be a comprehensive compendium of all of the organizations that have important roles in West German S/T activities. It will, however, provide a better understanding of the special features of the West German S/T system, as well as an idea of the variety of organizations, programs, and activities that are involved in the conduct of research and development.

the max-planck society

The Max-Planck Society—Max-Planck Gesellschaft (MPG) is one of the most famous and important performers of basic research in West Germany. It is financed largely (94 percent) by public funds from both the Federal and State Governments. Although this Society has considerable influence on the national R&D effort, its budget represents only about 2 percent of the national R&D expenditures in West Germany.

The Max-Planck Institutes are not expected to perform basic research in all fields. The Society supplements research in universities and is charged by the Science Council to carry out research that requires large or specialized facilities; to supply adequate human and financial resources to areas of particular scientific importance and promise; and to conduct research in emerging and interdisciplinary fields.[14]

Table 2 presents the Max-Planck Society's research funding in 1983 by field. Over 60 percent of the research funds are in natural sciences and most of the rest are invested in biomedical fields. The personnel are similarly concentrated. Of the more than 7,600 persons employed in Max-Planck Institutes in 1983, 67 percent were in natural sciences; 10 percent in medical fields, 8 percent in social sciences and humanities, 3 percent in engineering, and 2 percent in agriculture.[15]

The Max-Planck Society now consists of 52 institutes (table B-14), 3 clerical units, and 2 independent research groups. Independent research groups are a means through which new research efforts are promoted for a limited time—normally five years—and working relations between MPG and universities are increased.

[14]Robert Gerwin and Barbara Holtz, *The Max-Planck-Gesellschaft and Its Institutes* (Munich, West Germany: Max-Planck Institute, 1984).

[15]Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT), *Bundesbericht, op. cit.*

Table 2. Max-Planck Society R&D funding by field: 1983

[Dollars in millions]

Field	Amount	Percent
Total	$365.1	100
Astronomy and astrophysics	27.9	7.6
Chemistry	44.5	12.2
Physics I (basic research)	36.6	10.0
Physics II (materials)	92.2	25.3
Mathematics and computer sciences	6.0	1.6
Meteorology and aerospace research	25.0	6.9
Biomedical research in humans and primates	50.2	13.7
Biomedical research in model organisms	38.7	10.6
Psychology and biological aspects of behavioral research	12.1	3.3
Plant breeding and ecology	8.4	2.3
Law	9.6	2.6
History	5.1	1.4
Social sciences	8.7	2.4

NOTE: Figures are for current expenditures and include project funding. An additional $9.8 million is estimated for central expenditures, making an overall total of $374.9 million.

SOURCES: Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT) and Max-Planck Society—Max-Planck-Gesellschaft (MPG)

The importance of increased cooperation between the Institutes and universities is being emphasized. Nearly all directors of the Institutes and many other senior scientists are teaching at universities. The Institutes also offer research facilities to students working on their diplomas or doctorates. Of the approximatey 2,700 such young scientists and visiting scientists in 1981, 850 were working on their doctoral degrees. Recently the number of research projects conducted jointly by the Institutes and universities has increased. Competition between the two sectors remains, however, and many scientists feel that the research environment is better at the Institutes than at universities.[16]

fraunhofer society

The Fraunhofer Society—Fraunhofer Gesellschaft (FhG) is to applied research what the Max-Planck Society is to basic research. It is a nonprofit society that sponsors and performs applied research and development in three sectors of activity: Contract research, defense research, and services. The Society's main clients are industry and Federal and State Governments. In 1985, the Fraunhofer Society had a budget of DM400 million and a staff of around 3,700.[17] Over half of the personnel are in natural sciences and one-third in engineering. In terms of expenditures, however, about half are spent on engineering and more than 40 percent on natural science fields.[18]

This Society performs a mix of its own research projects as well as contract research. Twenty-two institutes are engaged in contract or project research with industry and government. Six institutes are devoted to defense research and are supported by the Ministry of Defense. The Society also provides technical information; technical evaluations; economic studies; and assistance in obtaining, maintaining, and exploiting patents. There are four institutes responsible for such services. The institutes conduct applied research and development in the following areas: [19]

- Microelectronics and sensor technology
- Information technology and production automation
- Material and building component behavior
- Production technologies
- Process engineering
- Energy and construction technology
- Environmental research
- Technical economic studies and technical information

The Federal and State Governments provide subsidies through the Fraunhofer Society to assist small- and medium-sized enterprises (under DM500 sales) for R&D projects leading to new or substantially improved products or processes and for technical assistance. The subsidies can amount to 40-60 percent of the R&D project's cost, depending on the technical and economic risk of the project.[20]

The Society's institutes have excellent links with industry. In addition to the contract work and technical assistance they provide to small- and medium-sized firms, many of the heads of the institutes are also on the boards of directors or are directors of research and development of some of the larger firms. They also have close links with universities. The institutes are usually located near research universities and more than half of the heads of institutes are also university professors. [21]

In 1973 a new model of financing research and development was introduced that is intended to stimulate contract research and further the Fraunhofer Society's role as an important catalyst in the transfer of technology from research laboratories to industry. Under this model, the Federal and State authorities grant the Society a certain amount of basic finance for a project, but the actual payment depends on the amount of money earned by the Society from contract research.[22]

More than half of the Society's budget was provided by the Federal and State Governments in the form of institutional funding in 1983 and about 40 percent came from contract research.[23] The importance of contract work is scheduled to increase until 1988 and in 1985 it is estimated that 60 percent of the Society's funds came from contract work.[24]

The Society is involved in performing research for the Ministry for Research and Technology in areas such as microelectronics, automation, and production technology (CAD/CAM and industrial robots); materials development (heavy

[16]Robert Gerwin and Barbara Holtz, *op. cit.*

[17]Fraunhofer Society—Fraunhofer-Gesellschaft (FhG), *Contract Research for Industry* (Munich, West Germany, 1985).

[18]Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT), *Bundesbericht, op. cit.*, pp. 395 and 374.

[19]Fraunhofer Society—Fraunhofer-Gesellschaft (FhG), *op. cit.*

[20]*Ibid.*

[21]Interview with the International Office, Fraunhofer Society, Munich, West Germany, October 1985.

[22]Valentin von Massow, *Organisation and Promotion of Science in the Federal Republic of Germany* (Bonn, West Germany: Inter Nations, 1983), p. 38.

[23]Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT), *Bundesbericht, op. cit.*, p. 63.

[24]Fraunhofer Society—Fraunhofer-Gesellschaft (FhG), *op. cit.* and annual reports.

duty ceramics, etc.); and biotechnology and gene technology.[25]

The State governments are also increasing their funding of Fraunhofer Institutes. In fact, there is competition between the German States in the founding of new Fraunhofer Society research facilities. The States in the northern part of West Germany are attempting to increase the incentives for high technology companies to settle there and the southern German States want to ensure their present competitive status by expanding their capabilities.[26]

large-scale national laboratories

In addition to the Max-Planck and the Fraunhofer-Gesellschaft Institutes, there are 13 national laboratories or big science establishments (grossforschungseinrichtungen). These laboratories receive funding from both the Federal and State Governments, but are supported primarily by the Ministry for Research and Technology. They were established to supplement the efforts of the universities in conducting research requiring large-scale instrumentation and large capital investments. The first centers were begun 25 years ago and were in the field of nuclear research. Other fields now include space research, mathematics and data processing, biotechnology, cancer research, environmental protection, marine, and polar research.[27] Table 3 lists the national laboratories and their budgets in 1983.

For many of these laboratories the research emphasis is obvious from their names. Nonetheless it may help to provide further information for some of them, especially in the area of nuclear research. The emphasis of the laboratory in Karlsruhe is on research using fast breeder reactors, and that of the laboratory in Juelich is on high-temperature reactors and fusion research. The Geesthacht laboratory also deals with nuclear research, but in the area of marine reactors. As an example of how the laboratories' research agendas are diversified and how the functional area can change, the Geesthacht laboratory also has done research in the area of desalination and sea-water chemistry, as well as in ocean environmental research and reactor safety.[28]

Even though these laboratories were established by Federal and State Governments and are financed almost completely by public funds, they are legally considered independent. Each institution has a supervisory board that establishes research priorities. The 13 laboratories are linked together under an Association of National Research Centers which coordinates their activities and represents their interests with the Federal Government.[29] But because the Ministry for Research and Technology provides almost all (90 percent) of the financial support for these centers, it understandably has a voice in the research priorities as well. The national laboratories conduct research in the various areas promoted by the Ministry for Research and Technology. The Ministry is considering reducing its investment in nuclear energy, and it remains to be seen how this will affect the research and operations of the national laboratories in the future. The research activities of some laboratories will likely be diversified into other priority areas.[30]

Table 3. Total budget of West-German large-scale national laboratories: 1983

[Dollars in millions]

Laboratories	Total
Total	$1,624.2
Alfred Wegner Institute for Polar Research, Bremerhaven (AWI)	19.9
German Electron-Synchrotron, Hamburg (DESY)	73.5
German Aerospace Research and Testing Institute, Porz (DFVLR)	178.2
German Cancer Research Center, Heidelberg (DKFZ)	46.3
Society for Biotechnological Research, Stoeckheim (Braunschweig)(GBF)	17.6
Research Center Geesthacht, Ltd., Geesthacht-Tesperhude (GKSS)	44.6
Society for Mathematics and Data Processing, Ltd., St. Augustin (GMD)	32.6
Society for Radiation and Environmental Research, Ltd., Munich (GSF)	67.8
Society for Heavy Ion Research, Ltd., Darmstadt (GSI)	36.9
Hahn-Meitner Institute for Nuclear Research, Ltd., Berlin (HMI)	47.5
Max-Planck Institute for Plasma Physics, Ltd., Munich-Garching (IPP)	60.0
Nuclear Research Plant Juelich, Ltd., Juelich (KFA)	204.5
Nuclear Research Center Karlsruhe, Ltd., Karlsruhe (KfK)	285.1

SOURCE: Federal Ministry for Research and Technology— Bundesministerium fur Forschung und Technologie, (BMFT), *Bundesbericht Forschung 1984*, 1984, p. 63.

federal and state research establishments

In addition to the research laboratories mentioned previously, the Federal Government maintains about 40 research establishments (Bundesforschungsanstalten), most of which perform mission-related research for their respective ministries. The various States also own and support about 50 of their own research laboratories (Laenderforschungsanstalten) which generally conduct applied research and development important to their particular region and economy.[31] In addition, there are 48 research institutions that are about equally funded by the Federal and State Governments and which are normally referred to as the "Blauen Liste" (Blue-List) institutes. They perform research that is usually more basic in nature than that of the aforementioned Federal and State research enterprises. A general requirement of these institutions is that they

[25]Fraunhofer Society—Fraunhofer Gesellshaft (FhG), *Annual Report 1983* (Munich, West Germany, 1984).

[26]*Ibid.*

[27]Catherine P. Ailes, *et. al., Performer Organizations and Support Strategies for Fundamental Research: United States, France, West Germany, United Kingdom, Japan, and the Soviet Union* (Arlington, Va.: SRI International, 1985).

[28]Hildegard and Reinhold Geimer, *op. cit.* and Valentin von Massow, *op. cit.*

[29]*Ibid.*

[30]Interview with Federal Ministry for Research and Technology—Bundesministerium fur Forschung Technologie (BMFT) officials, Bonn, West Germany, October 1985.

[31]Hildegard and Reinhold Geimer, *op. cit.*

conduct research of a multiregional or national importance. In 1984 their total budget was over $270 million and they employed 5,150 persons.[32]

german research society

The German Research Society—Deutsche Forschungsgemeinschaft (DFG), is an autonomous organization somewhat similar to the National Science Foundation, in that it finances research and development on a proposal review basis, relying on expert peer review. In addition to funding research proposals, the German Research Society is responsible for supporting the training of young scientists, fostering cooperation between researchers—including international cooperation, and providing advice on scientific matters to policymakers.[33] The Society does not have research institutes of its own and is not a research performer; rather it distributes R&D funds, mainly to the higher-education sector.

The Society receives most of its funding from Government sources. In 1984, 58 percent of its budget of approximately $440 million came from the Federal Government and 41 percent from the State governments. Table 4 presents a breakdown of its budget by major field.[34] About a third of the Society funds were allocated to life sciences—an area for which funding appears to be increasing.

The largest proportion (45 percent in 1984) of the Society budget is allocated to the support of its normal or core program in which individual researchers initiate their own proposals and select their own topics. The Society also spends about 13 percent of its funds on proposals under a priority program (Schwerpunktverfahren Programme).

Table 4. German Research Society budget by field: 1984

[Dollars in millions]

Field	Amount	Percent
Total	$440	100.0
Physical sciences and mathematics	111	25.1
Engineering	100	22.6
Life sciences	142	32.2
Environmental research	21	4.9
Social sciences and humanities	67	15.1

NOTE: Because of rounding, components may not add to totals.

SOURCE: German Research Society—Deutsche Forschungsgemeinschaft (DFG), *Tatigkeitsbericht*, 1984

For a limited time, the priority program supports research in those fields determined by the Senate of the Society to be priority areas, and for which it seeks to improve West German capabilities in order to match international standards.

A special collaborative program (Sonderforschungsbereiche) that not ony fosters cooperation, but also promotes interdisciplinary research, was established in 1968 at the recommendation of the Science Council. Under this program, the Society provides long-term, but not permanent, funding; it allocated about 30 percent of its budget to this program in 1984. An institution or university, rather than a group of individuals, develops a proposal in which it must prove that the institution is committed to long-term support of the research. Such a proposal must be examined and agreed to by peer review. Unlike the other programs, this one is financed primarily (75 percent) by the Federal Government.

A university must identify an area in which it excels and has achieved eminence, and the university or State Government must commit itself to continue funding the area after the Society support ends. One could consider these sites at which special collaborative programs are developed to be centers of excellence in a particular field, although they may not be the only centers of excellence in that field. One of the first special collaborative programs was so successful that it has now become a Max-Planck Institute for Mathematics. Table B-15 lists the special collaborative programs that were supported by the Society in 1985 and their location. These programs have wide leverage in their abilities to invite international scientists and engineers to work with them and in some cases can even pay their expenses. In fact, one of the criteria by which a program is evaluated every three years is its international standing, which is calculated in part on the identities of the scientists, engineers, and publishers who have agreed to associate themselves with the program. These fields may be some of the best for potential scientific cooperation or collaboration between West Germany and the United States.[35]

The Society is also responsible for adminstering special fellowship programs, e.g., the Heisenberg Program for the Assistance of Highly-Qualified Young Scientists. This program was established in 1977 and is equally funded by the Federal and State Governments. In 1984 it was allocated between 1 percent and 2 percent of the Society's budget, or about $6 million.[36] The program was established to enable young scientists whose positions were insecure to remain actively involved in research activities. This is especially important given the tight job situation in academia. The average period of support is for two years but can be renewed up to five years. The Society is in the process of creating a new postdoctoral research program, and is considering launching a new award program which would provide 10 to 25 of the top research scientists to do whatever research they deem important, without requiring specific proposals.[37]

confederation of industrial research associations

The Confederation of Industrial Research Associations—Arbeitsgemeinschaft Industrieller Forschungsvereinigungen (AIF) is an auton-

[32]Bund-Laender-Kommission fur Bildungsplanung und Forschungsforderung, *Einrichtungen der Blauen Liste: Rechtsgrundlagen und Allegemeine Informationen* (Bonn, West Germany, 1984).

[33]Hildegard and Reinhold Geimer, *op. cit.*

[34]German Research Society—Deutsche Forschungsgemeinschaft (DFG), *Tatigkeitsbericht* (Bonn, West Germany, 1984).

[35]*Ibid.* and interview with German Research Society officials, September 1985.

[36]German Research Society—Deutsche Forschungsgemeinschaft (DFG), *op. cit.*

[37]German Research Society—Deutsche Forschungsgemeinschaft (DFG) interview, *op. cit.*

omous organization that finances and coordinates cooperative industrial research—generally applied research and development. This organization is particularly important to the traditional industrial firms of small and medium size that find it difficult to support research and development on their own. It was founded in 1954 and is now an umbrella organization encompassing 92 member associations, many of which have their own research institutes; the Conferation has 63 of its own. Industry supports most of its activities, but funds are also received from the Federal Government, particularly from the Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT) and the Ministry of Economics (BMWi).[38]

If there is a problem, common or generic to the member associations, a research proposal can be made to the Confederation which relies on a group of 120 experts, who represent various fields, to evaluate the proposals received. About half of these experts are from industry, and half are from universities and research institutes. Reviewers must determine if the proposed project is technically sound and of scientific interest, whether the project is of economic interest to small- and medium-sized firms, and whether sufficient resources are devoted to the projects. If the project application is approved, it will be supported with funds from the Ministry of Economics on the condition that the industrial associations can show that they are expending R&D funds of their own on cooperative research and development.

The AIF is also responsible for administering the Federal Government's R&D labor support project for small- and medium-sized firms which began in 1978. The exact terms have changed slightly over the years, but essentially they permit the Ministry of Economics to subsidize 40 percent of the labor costs for scientists, engineers, and technicians engaged in research and development for those firms with annual sales of DM50 million and not more than 500 employees. It will also pay 55 percent of the labor costs for new R&D personnel if the firm can show that it has increased its R&D efforts. In 1985 the program was expanded to include payment for 45 percent of labor costs associated with *new* R&D personnel in those firms with annual sales of DM200 million and 1,000 employees. The firms must submit detailed applications to AIF to receive such support. This program was on hold for most of 1985 while the European Economic Community (EEC) decided if it is allowable under their regulations and guidelines for fair competition. In August 1985 the EEC determined that the plan was allowable and it is now scheduled to continue until 1989.

The Confederation also administers the Ministry for Research and Technology's program that encourages small- and medium-sized firms to contract for R&D projects. The program subsidizes the costs of an R&D project contracted out with external research bodies (including universities, research organizations, and even foreign institutes). The Federal Ministry for Research and Technology subsidizes up to 40 percent of the costs of extramural R&D projects for those firms that have up to DM50 million in annual sales and up to 30 percent of the costs for those firms that have annual sales of up to DM500 million.

the science council

The main coordinating body in West Germany between the Federal Government, State Governments, and the scientific community is the Science Council—Geschaftsstelle des Wissenschaftsrates (WR). It was founded in 1957 by an administrative agreement between the Federal and State Governments. It provides advice and recommendations on science policy matters, especially those concerning the higher education sector. It does not have executive powers, but its recommendations carry a great deal of weight and are generally accepted because they constitute the concensus of the Council whose members represent a variety of sectors and disciplines. An example of one of its recommendations was the establishment of the special collaborative programs (sonderforschungsbereiche) that are now sponsored by the German Research Society.

It is not a funding or granting organization. Nonetheless, it is mandated to review annually the planned expenditures of the Federal and State Governments for higher education, including university proposals for new laboratories, scientific equipment, etc. The Council is thereby able to reduce duplication of effort in terms of major scientific equipment and facilities and can expedite the establishment of centers of excellence.[39]

The Council is currently working on an extensive review of the health of West German universities. It is concerned about a number of problems including the age structure of university faculty. Most of the university positions are currently filled by tenured professors who were hired during the expansion period of the 1960's and 1970's. Since most of these professors will not be eligible to retire for 20 years, there is little room for bright young investigators to enter academia. Moreover, many of the faculty positions needed to be filled rapidly during the earlier expansion, and some of the current faculty may be less qualified than the young investigators.

In order to create new positions, universities must justify them by introducing new specialties. This has led to another problem that concerns the Science Council: the overloading of the university curricula. The academic requirements in individual disciplines have become so cumbersome that it is virtually impossible for students to complete their

[38]Information in this section was obtained in an interview with AIF officials in Cologne, West Germany, September 1985, and from the Confederation of Industrial Research Associations—Arbeitsgemeinschaft Industrieller Forschungsvereinigungen (AIF), *Handbuch, 1984* (Cologne, West Germany, 1984).

[39]The material for this section was obtained from interviews with staff members of the Science Council—Geschaftsstelle des Wissenschaftsrates (WR), Cologne, West Germany, September 1985.

studies in four years. The Science Council is considering restructuring the higher educational training system to shorten the length of the first degree programs and to strengthen graduate education, including that of the role of research and development.

These are just some of the science policy problems that the Science Council is addressing. Other issues with which they are concerned include the importance of outside funding for universities and research institutions, mobility for researchers, increased competition between German States for R&D facilities, employment problems, and evaluation of the quality of education and research and development.

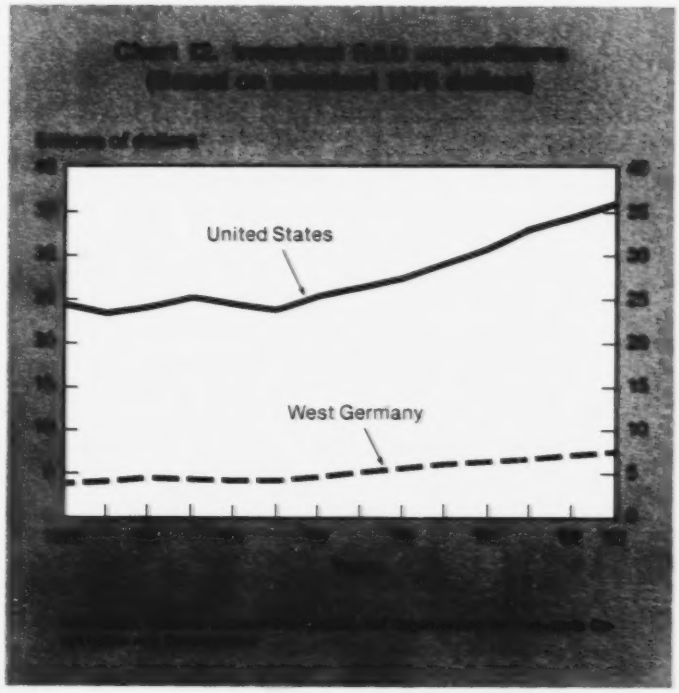
industrial research and development

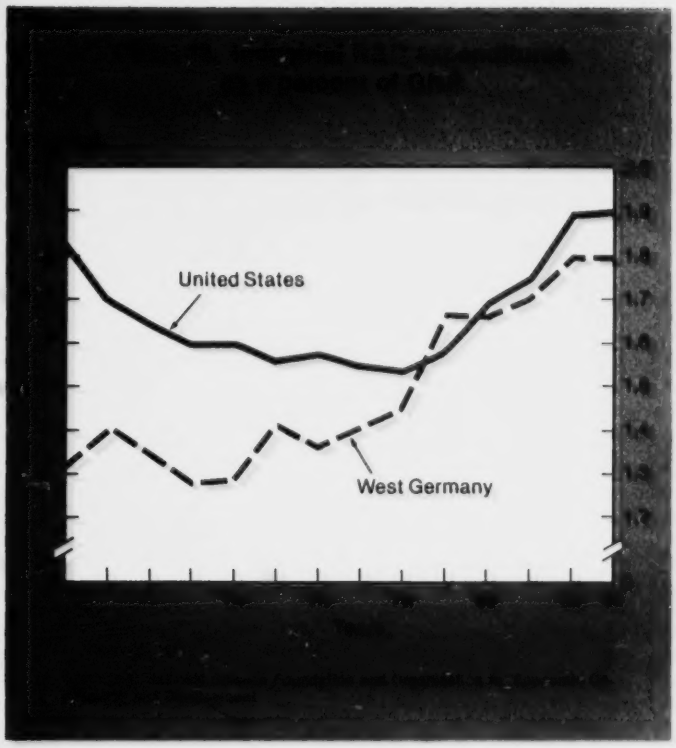
overall industrial r&d trends

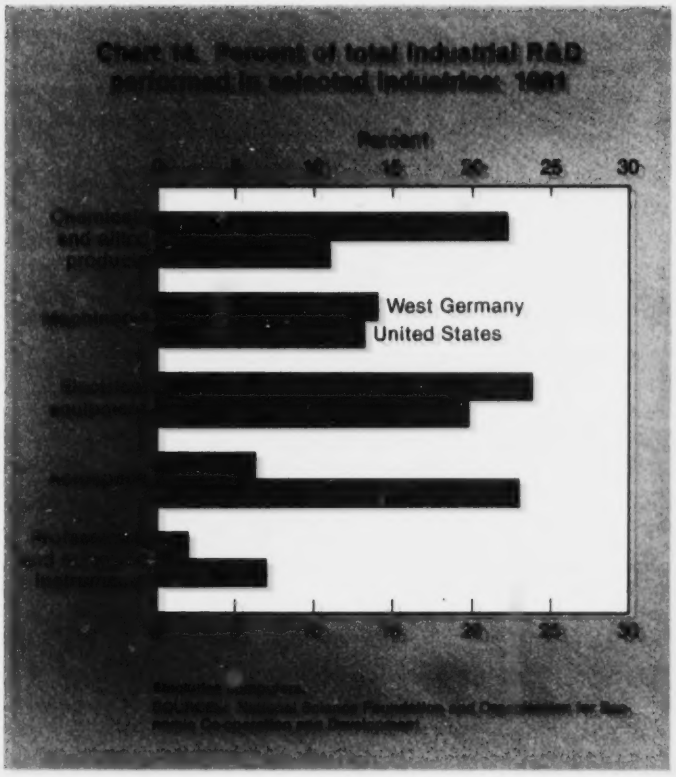
With its increased awareness of the importance of science and technology to international industrial competitiveness, West Germany is investing greater amounts of resources in industrial research and development. About 70 percent of all West German R&D expenditures was invested in the industrial sector in 1983, up from 64 percent in 1970. In the United States over 70 percent of the Nation's research and development also is performed in industry.

In 1983, West Germany invested DM30 billion in industrial research and development or 7.3 billion in constant dollars (chart 12). During the period 1970-79, industrial R&D expenditures increased more rapidly in real terms in West Germany (64 percent) than in the United States (18 percent). Since 1979 the growth in West German industrial research and development has slowed (chart 12). Industrial research and development rose 25 percent in real terms in the United States between 1979 and 1983 compared with only 10 percent in West Germany.

Examination of industrial R&D expenditures as a percent of the gross national product (chart 13) shows that although West German industrial R&D growth slowed, it increased at a much faster pace than the economy from the midseventies to 1982. Data for 1983 indicate a leveling in the trend over the last five years, but it is still too early to tell if this is a temporary pause or a significant trend change. In 1983, the West German industrial R&D/GNP ratio remained at 1.8 percent. U.S. industrial R&D/GNP ratios have continued to grow since 1978, climbing to 1.9 percent in 1983.







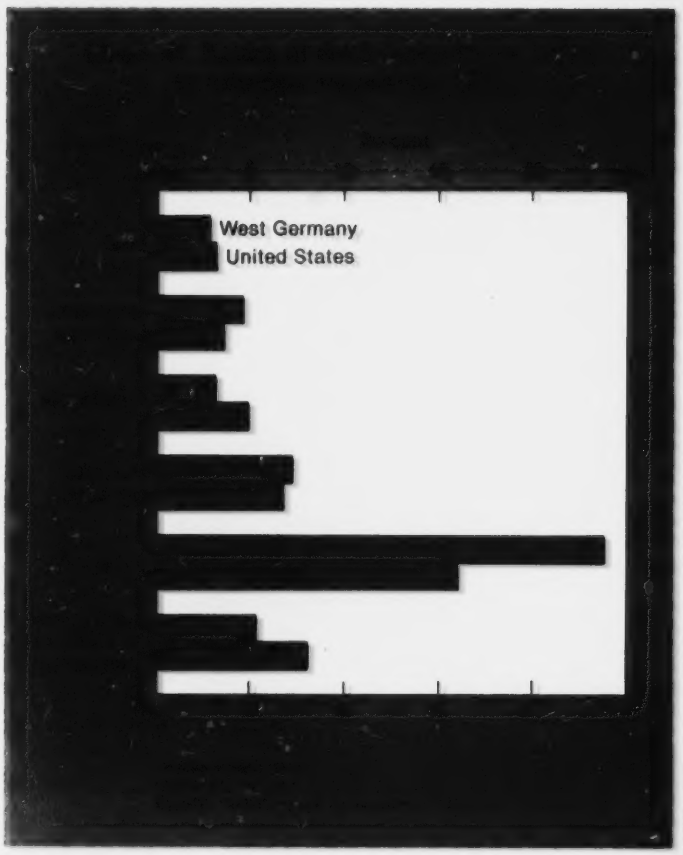
The 1983 leveling of West German industrial R&D expenditure coincides with the decision of the West German Government to decrease direct funding of industrial research and development in favor of indirect mechanisms to improve the climate for industrial spending. The reorientation of West German research and technology policy that took place in 1983 called for increased reliance on private initiative and entrepreneurial responsibility and restraint by the Government with regard to support of research and development in industry—particularly in advanced development projects. Public funds are to be used primarily in these areas where the Government has its own particular responsibilities or where overriding social or macroeconomic concerns warrant governmental support of research and development.[40] This is not unlike the thrust of current U.S. S/T policy.

[40]Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT), *Bundesbricht*, *op. cit.*, p. 13.

industrial r&d concentration by industry

The concentration pattern of industrial research and development in West Germany is quite different from that of the United States. In 1981, R&D expenditures were twice as concentrated in the chemical and allied products industries in West Germany as they were in the United States (chart 14). U.S. industrial R&D expenditures were more highly concentrated in the aerospace industry (23.1 percent), which was the leading U.S. industry in terms of total R&D investment in 1981. In West Germany, the leading industry was electrical equipment. Although its concentration has decreased slightly since 1971, about one-fourth of all West German industrial research and development was still invested in this industrial group in 1981. The proportion of West German industrial R&D expenditures in machinery increased over the decade from 10.2 percent in 1971 to 14.1 percent in 1981. Research and development in computers are included in this group (according to the International Standard Industrial Classification) and most likely represent an important part of this growth, but the exact contribution is not known because data on research and development for computers is not separately identified.

The leading West German industry in terms of company R&D expenditures is chemicals and allied products, which expended more than one-fourth of all company R&D funds in 1981. The electrical equipment industry also expended 25 percent of all company R&D funds in West Germany, compared with only 18 percent in the United States (chart 15). When Government funds are excluded, the U.S. concentration in aerospace research and development is diminished to only 10 percent, but is still substantially more than the West German proportion.



r&d-to-sales

The perceived importance of investing in research and development varies by country and industry. One way to determine the relative importance accorded research and development by a given country or industry is to measure the proportion of available income being invested therein. The ratio of industrial R&D expenditures to net sales provides a measure of R&D intensity that can be compared across industries and countries (chart 16).

In 1981, the R&D-to-sales ratio for all industries was 2.8 percent in West Germany, compared with 3.1 percent in the United States. Using this measure, the aerospace industry is the most R&D-intensive in both countries. Although West German industry as a whole was slightly less R&D-intensive than U.S. industry in 1981, West Germany had a much higher R&D-to-sales ratio in the aerospace industry and somewhat higher ratios in the chemicals and allied products and electrical equipment industries.

Since 1979, U.S. ratios of R&D-to-sales have increased for the industrial sector as a whole as well as for each of these selected industries. R&D intensity increased for West German industry as a whole between 1979 and 1981, but decreased in the professional and scientific instruments and the aerospace industries. One of the major reasons for the difference in R&D intensity in the aerospace industry in West Germany and the United States is the large volume of U.S. sales: in 1979, U.S. sales in the aerospace industry were over 40 times those of West Germany. By 1981, West German aerospace sales had increased over 50 percent and U.S. sales were only about 25 times the value of West German sales. This decrease in the differential in sales between the two countries led to a narrowing of the R&D-intensity difference. In fact, the overall difference in R&D intensity of the aerospace industry in West Germany and the United States decreased 10 percentage points between 1979 and 1981.[41]

[41]Because the aerospace industry is one in which there is cooperation between European companies, the research and development performed in Germany may be benefiting sales of companies located in other European nations. Such sales figures would not be captured in national data. This may also be another factor resulting in R&D-to-sales ratios that are higher in West Germany than in the United States. The German R&D-to-sales ratios and sales data are based on national data. See Helga Echterhoff-Severitt, *Forschung und Entwicklung (FuE) in der Wirtschaft 1979*, 1981, and Helga Echterhoff-Severitt, *Forschung und Entwicklung (FuE) in der Wirtshaft 1981*, 1984 (Essen, West Germany).

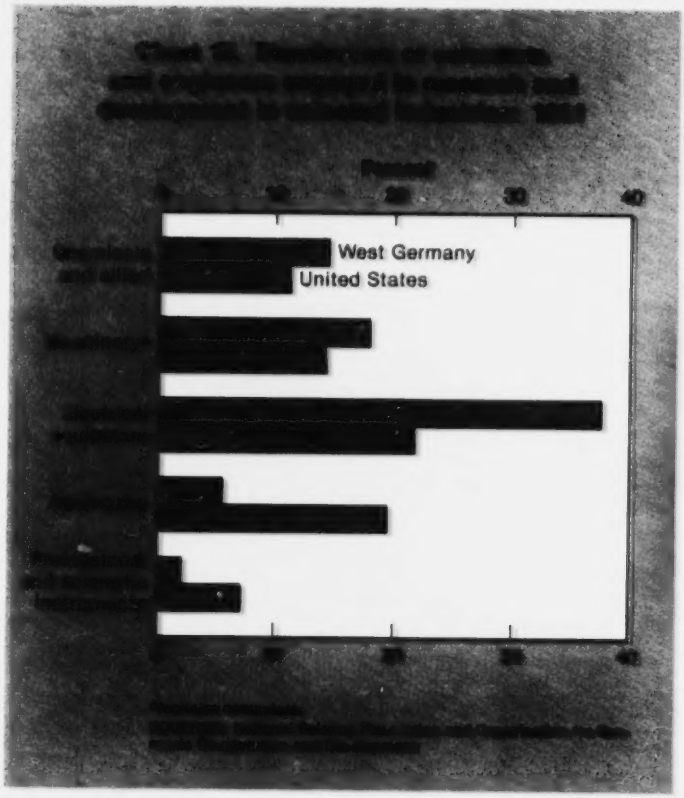
r&d scientists and engineers in industry

As research and development has become increasingly important to industrial competitiveness, many countries have increased their employment of industrial researchers. Over 77 thousand scientists and engineers were employed in research and development in West German industries in 1981. Between 1979 and 1981, about 3.5 thousand new researchers were employed by West German industries, representing an increase

of 5 percent. The U.S. increase in scientists and engineers engaged in industrial research and development rose 15 percent over the same period, reaching 488 thousand by 1981.

By far the greatest percentage of these scientists and engineers in both countries are in the electrical equipment industry (chart 17), with West Germany having a much higher concentration. In 1981, 38 percent of all West German industrial scientists and engineers engaged in research and development were employed in this industry compared with 22 percent in the United States. In addition to electrical equipment, West Germany's concentration of R&D scientists and engineers in the chemical and machinery industries is higher than that of the United States.

Demand for electrical engineers is high in both countries, fueled by technological developments in microprocessors and robotics/automation. A survey of U.S. industrial firms in the early 1980's found that over one-half of the firms reported shortages in electronic, electrical, and computer engineers. Although these shortages had declined considerably by 1983, employers were still projecting high demand for these fields.[42] The number of first degrees in electrical engineering actually declined in the United States during the 1970's thereby exacerbating the problem. This trend, however, has also been reversed.[43]



Because the supply of electrical engineers in West Germany has generally exceeded the demand, enrollments of new students in this field temporarily decreased by almost one-fifth from 1976 to 1980. West Germany expects a fairly strong demand for electrical engineers throughout the eighties and has taken measures to increase enrollments in this field.[44]

The Employment Service and the Association of Electrical Engineering and Technology firms began a massive public awareness campaign to explain the opportunities of a career in electrical engineers. A concerted effort was made to advise high school teachers and students of the courses that the students should select in order to prepare for further study in engineering. In addition, the firms financed introductory courses in colleges to assist students in getting the necessary background course work to begin their college studies. These efforts were successful. Between 1980 and 1983, electrical engineering enrollments had increased substantially—about 60 percent.[45]

[42]National Science Foundation, "Industry Reports Shortages of Scientists and Engineers Down Substantially From 1982 to 1983," *Science Resources Studies Highlights* (NSF 84-303)(Washington, D.C., Feb. 17, 1984).

[43]National Science Foundation, *Science and Engineering Degrees: 1969-80* (NSF 82-307)(Washington, D.C., 1982).

[44]Mintzes and Tash, *op. cit.*, pp. 135-137.

[45]*Ibid.* and Hans-Jurgen Block, "Aktuelle Daten zum Studium und zum Arbeitsmarkt von Ingenieuren und Naturwissenschaftlern," *Beitrage zue Hochschulforschung* (Munich, West Germany, 1985).

higher education

overall R&D trends

It is difficult to make international comparisons of the resources devoted to research and development in the higher education sectors. For purposes of this report, the OECD definition of the higher education sector is used: It comprises all universities, colleges of technology, and other institutes of postsecondary education whatever their legal status or source of funding, and includes all research institutes, experimental stations, and clinics operating under the direct control of, administered by, or associated with higher education establishments. In the United States, for instance, R&D expenditures in the higher education sector would include R&D funds spent not only in universities and colleges but also in federally funded research and development centers (FFRDC's) administered by individual universities and colleges and by university consortia. In contrast to the U.S. system of relying principally on separately-budgeted R&D project awards, West Germany depends on a dual system of institutional funding (including support for facilities) and project support for academic research. Universities and colleges receive general university funds for teaching and research, as well as facilities and equipment, primarily from the State Governments, but also from Federal agencies such as the Federal Ministry of Education and Science; and R&D funds for special projects or programs are received directly from Government organizations such as the Federal Ministry for Research and Technology as well as indirectly through the autonomous German Research Society. The Society is jointly funded by the Federal and State Governments and also receives some private financial support.

The U.S. data relative to West Germany are somewhat underestimated for a number of reasons. The West German R&D data for the higher education sector are national estimates derived from a survey of total higher education expenditures and personnel. Adjustments are made to exclude non-R&D items and then estimates are made on the basis of time spent on research and development for various fields and types of institutions. Only that portion of salaries associated with time spent on research is included.[46] U.S. R&D expenditures for higher education are based on annual surveys. They cover only separately budgeted research and development and exclude departmental research undertaken in conjunction with teaching. In addition, West German higher education R&D data include research and development in the humanities together with social sciences. These represent only about 1 percent to 2 percent of total West German R&D expenditures and about 10 percent of higher education research and development. Adjustments were made to exclude R&D expenditures for humanities when discussing distribution by field.

R&D expenditures in the West German higher education sector rose 60 percent in current terms over a 10-year period and reached DM6.8 billion in 1983. In constant dollar terms, however, very little growth was experienced over the period, and expenditures actually declined after 1981 (chart 18). In contrast, following an initial drop in the early seventies that was due largely to a decrease in real Federal funding,[47] the higher education sector in the United States enjoyed a 28-percent real increase from 1974 to 1983.

[46]Organisation for Economic Co-operation and Development (OECD), "International Statistical Year 1981: Germany," (Paris, France, 1984.)

[47]National Science Board, *Science Indicators—1982* (NSB 83-1)(Washington, D.C.: Supt. of Documents, U.S. Government Printing Office), p. 305.

In 1983, R&D expenditures in the higher education sector totaled 1.7 billion constant dollars in West Germany compared with 6.7 billion constant dollars in the United States. Although the latter Nation spent four times that of West Germany in absolute terms, West Germany invested about the same, relative to the size of its economy even when expenditures for humanities are excluded. In both countries, R&D expenditures represented about 0.4 percent of the gross national product in 1983.

Although only 17 percent of all West German R&D funds were spent in higher education in 1981, almost one-fourth of its scientists and engineers engaged in research and development were employed in higher education. In the United States, these two types of resources were more closely matched: 13 percent of the R&D funds were invested in this sector in 1981, and 14 percent of all R&D scientists and engineers were employed in higher education.

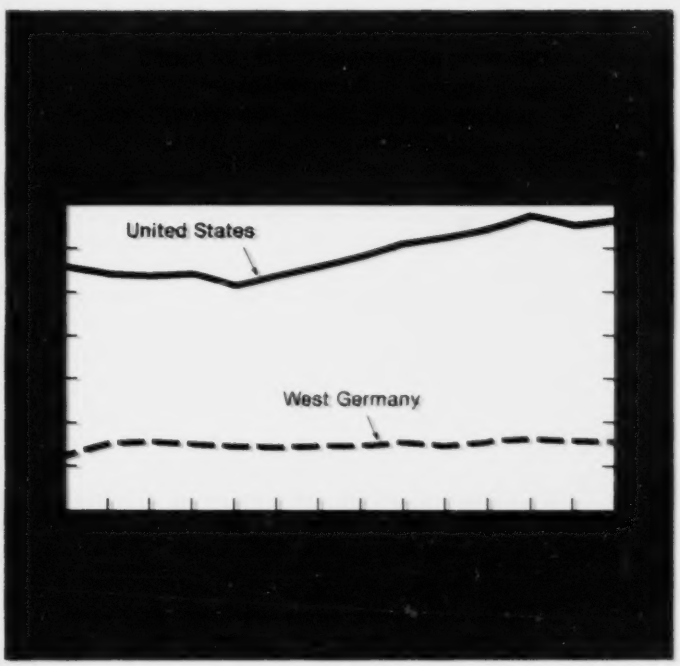
Although the share of R&D funds declined, the number of scientists and engineers engaged in research and development increased in both countries. Between 1971 and 1981, R&D scientists and engineers employed in the higher education sector increased 47 percent in West Germany, reaching a level of 30.2 thousand; in the United States, the number of these personnel rose 24 percent over the same period to a level of 98.7 thousand.

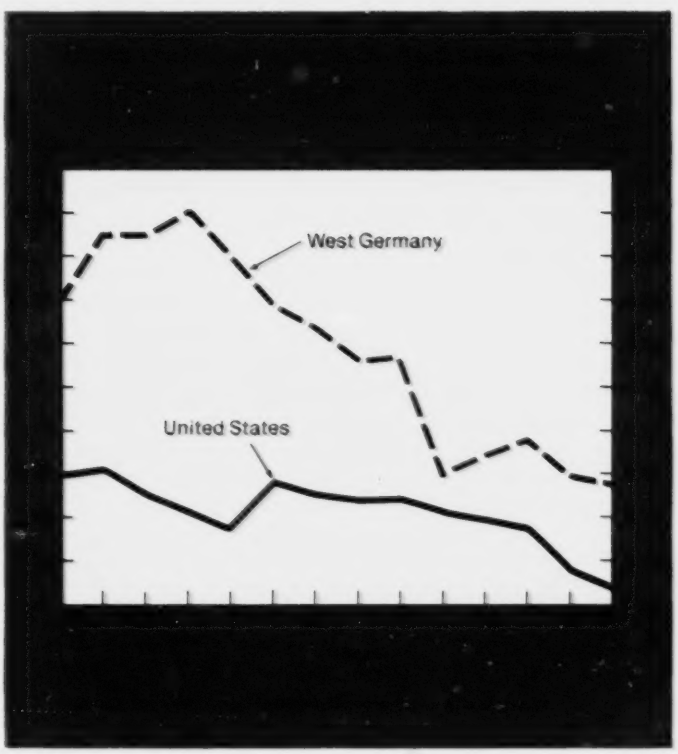
The higher education sector represents a greater proportion of the Nation's research and development in West Germany than in the United States, but the role of this sector as a performer of research and development has declined in both countries. The higher education share of total R&D funds declined in West Germany from 20 percent in 1970 to 16 percent in 1983. In the United States, there was less of a decline, from about 16 percent in 1970 to 13 percent in 1983 (chart 19).

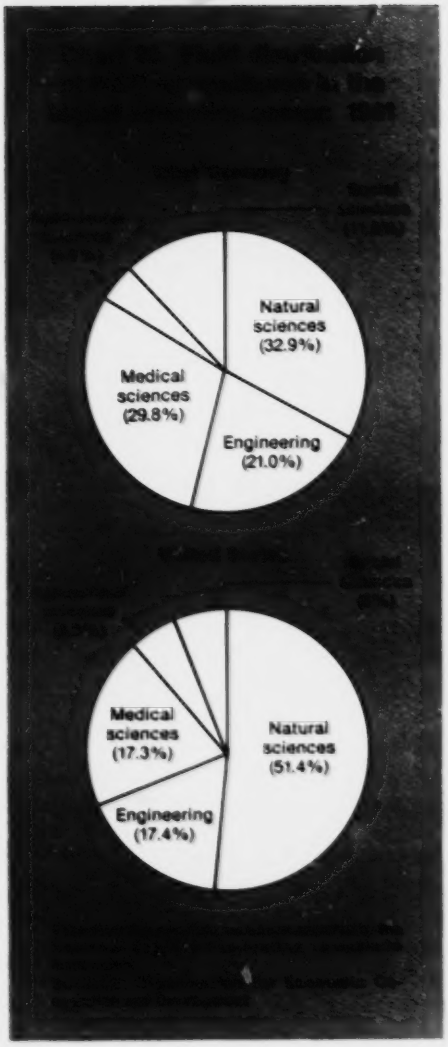
[*]Organisation for Economic Co-operation and Development (OECD).

research and development by field

Universities and colleges are the major performer of basic research in both countries. About 60 percent of basic research expenditures are spent by the higher education sector. Since very little development is carried out in academe, the distribution of current R&D expenditures by field is essentially the field distribution of research (chart 20). West German R&D expenditures in the social science fields of higher education have been adjusted here to exclude R&D expenditures in the humanities. Natural sciences consume the lion's share of R&D expenditures in both countries. In 1981, over half of all U.S. expenditures and one-third of West German research and development in the higher education sector went to natural science fields. West Germany spent a somewhat higher







proportion in engineering (21 percent) and in medical sciences (30 percent) than did the United States (17 percent in each).

An examination of R&D scientists and engineers by field in 1981 shows somewhat similar patterns with a few exceptions. In West Germany, about 9,300 natural scientists and 5,700 engineers were employed in research and development on a full-time-equivalent basis. The shares of R&D expenditures match closely the proportions of R&D scientists and engineers in all the fields except medical sciences and social sciences. Medical sciences received 30 percent of the R&D funds spent in the higher education sector, but less than 20 percent of the researchers employed larger shares of the R&D scientists and engineers.

In the U.S. higher education sector, there were 459,000 natural scientists and 16,600 engineers engaged in research on a full-time-equivalent basis. The U.S. concentration of R&D expenditures was somewhat greater (51 percent) than the share of R&D personnel resources in the natural science fields (47 percent), and about the same (17 percent) for engineering. The agriculture, medical, and social science fields all receive a somewhat smaller proportion of the R&D funds expended by the higher education sector than their share of the R&D scientists and engineers.

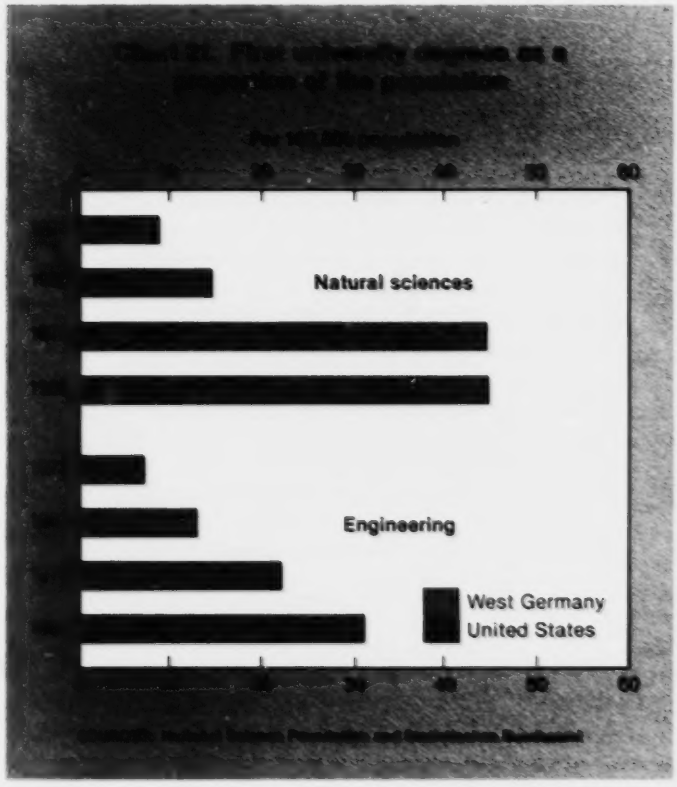
s/e degree production

Although the higher education sector performs a major role in research, its primary responsibility is education. Research is closely coupled to teaching in West Germany as well as the United States, and the output of trained scientists and engineers is an invaluable contribution to these nations' S/T capabilities.

Although West Germany has a large professional school system (to be discussed later), comparisons here concentrate on university level degrees. The number of first university diplomas awarded by West Germany in the natural science fields[49] increased 65 percent from 5,400 in 1973 to 8,900 in 1983. Over the same period the number of U.S. bachelor degrees in natural sciences increased only 11 percent reaching 104,800 in 1983. The United States, however, grants more than three times the number of natural science degrees relative to its population than does West Germany: in 1983, 14 to 15 out of every 100,000 persons were awarded a university diploma in natural sciences in West Germany compared with almost 45 in the United States (chart 21).

First university diplomas awarded in engineering increased over 70 percent in West Germany during the 1973-83

[49]Includes physical sciences, mathematics and computer sciences, and biological sciences. Agricultural degrees are considered separately for purposes of international comparisons.



period and reached a total of 7,700. The United States graduates a larger number and a higher proportion of university-trained engineers relative to its population than does West Germany. In 1983, 12 to 13 out of every 100,000 persons in West Germany received a university engineering diploma compared with 31 in the United States.

In West Germany, an engineering degree can be earned from either a university or a fachhochschule (professional college). The university course is a five-year program roughly equivalent in years of training to between a U.S. bachelor's and master's level degrees. It consists of broad academic engineering training and usually some work experience in industry. After completing the course work, a student must pass a State examination to qualify as a "diploma engineer."

Fachhochschulen provide practical training that is shorter and more specialized than university training and that lacks the broader range of courses in the sciences and management sciences available in universities.[50] They are an important source of training in engineering skills, but only a minor source of training for scientists. In 1983, there were 14,900 fachhochschule graduates in engineering and only 1,100 in natural sciences.[51] Twice as many students graduate with engineering training from fachhochschulen as from universities. If one were to consider these technical engineers together with the university-trained engineers, then West Germany's proportion of engineering degrees per 100,000 population would be 37, which is a higher concentration than that of the United States.[52]

The fachhochschule technical engineers play an important part in the German economy. They undoubtedly increase the technical competency of the German labor force and many of the fachhochschule engineers are employed in industry. In fact this type of training may be particularly useful for industry. Nevertheless, this report concentrated primarily on comparisons of university degree data for reasons of comparability with U.S. data on engineering. The training of technical engineers does not appear to be equivalent to that of the university-trained diploma engineer. For example, very little research is conducted at the fachhochschule. In addition to the difference in length of study, one cannot study for a doctorate in engineering after graduating from a fachhochschule unless undergraduate studies are repeated at a university. Furthermore, there has been considerably more unemployment among the ranks of technical engineers than among those engineers who are university trained: twice as many engineering graduates from professional colleges were unemployed (14.2 thousand) in 1983 as those who graduated from universities (7.2 thousand). In fairness, however, it should be remembered that there are twice as many graduates from these technical colleges as there are from universities. The importance of this engineering degree may be increasing and there is evidence that West Germany may phase out this two-tiered degree system in favor of one engineering degree.[53]

West Germany has considerably increased its doctoral production in natural sciences and engineering fields. The number of doctorates granted in natural science fields rose 35 percent from 2,000 in 1973 to 2,700 in 1983. Over the same period the number of U.S. degrees in natural sciences actually declined 9 percent from almost 9,000 to about 8,200. The U.S. decrease occurred primarily in the physical and mathematical sciences.[54] The number of engineering doctorates in West Germany increased 43 percent during the 1973-75 period, and maintained an annual level of 1,000 through 1983. The United States experienced a 25-percent decrease in the number of engineering doctorates granted from about 3,400 in 1973 to 2,500 in 1981. This trend, which is influenced by labor market demand, seems to be reversing itself, however, because some increase in U.S. doctoral degrees in engineering occurred between 1981 and 1983. Most of this increase, however, was accounted for by foreign students who constituted 56 percent of the U.S. engineering doctorate recipients in 1983.[55]

As a result of these trends in degree production, West Germany has overtaken the United States in terms of the number of S/E doctorates awarded as a percent of the population (chart 22). In 1973, the United States graduated 4.2 natural science doctorates per 100,000 population, compared with 3.2 for West Germany. In 1983, however, the West German ratio for natural science doctorates (4.4) was higher than the U.S. ratio (3.5). A similar pattern occurred in the field of engineering. Although the U.S. ratio of doctorates per population was higher in 1973, 10 years later the opposite was true. In 1983, West Germany granted 1.6 doctorates in engineering for every 100,000 persons. The engineering doctorate degree ratio in the United States was lower at 1.2 per 100,000 population.

The West German Government has emphasized the importance of providing outstanding educational opportunities in science and technology. It has initiated a number of programs such as the Heisenberg and AGF (Association of Big Science Establishments) programs by which young investigators can experience work in large-scale facilities and research institutes. A new program would enable young scientists and engineers from industry to receive additional training in key technology areas at research institutes. The States in West Germany are primarily responsible for education, and they have recently initiated new doctoral programs.[56]

[50]Mintzes and Tash, *op. cit.*

[51]Der Bundesminister fur Bildung und Wissenschaft, *Grund-und Strukturdaten 1984/85* (Bonn, West Germany, 1985) and Statistisches Bundesamt, *Prufungen an Hochschulen 1983* (Weisbaden, West Germany, 1983).

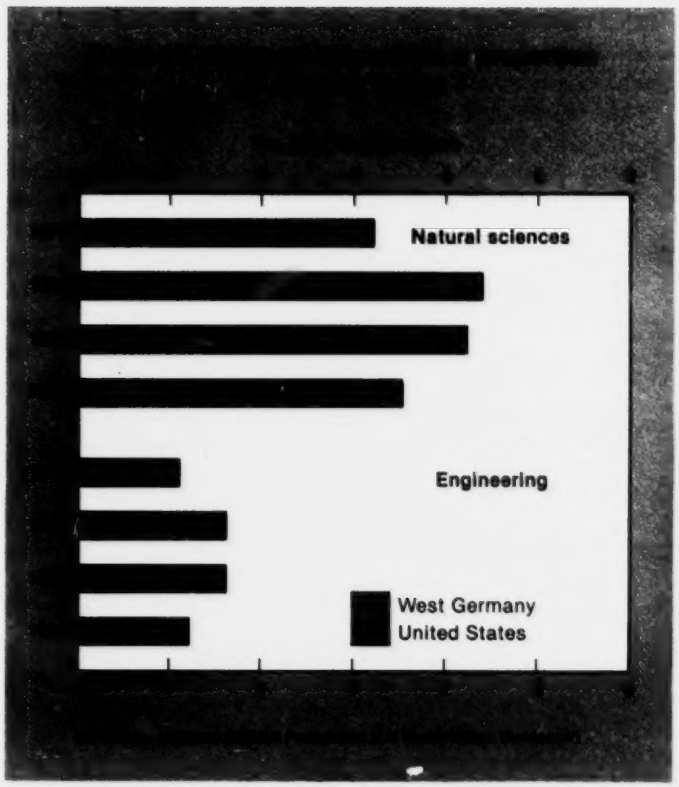
[52]National Science Foundation and *Grund-und Strukturdaten 1983/84*, *op. cit.*

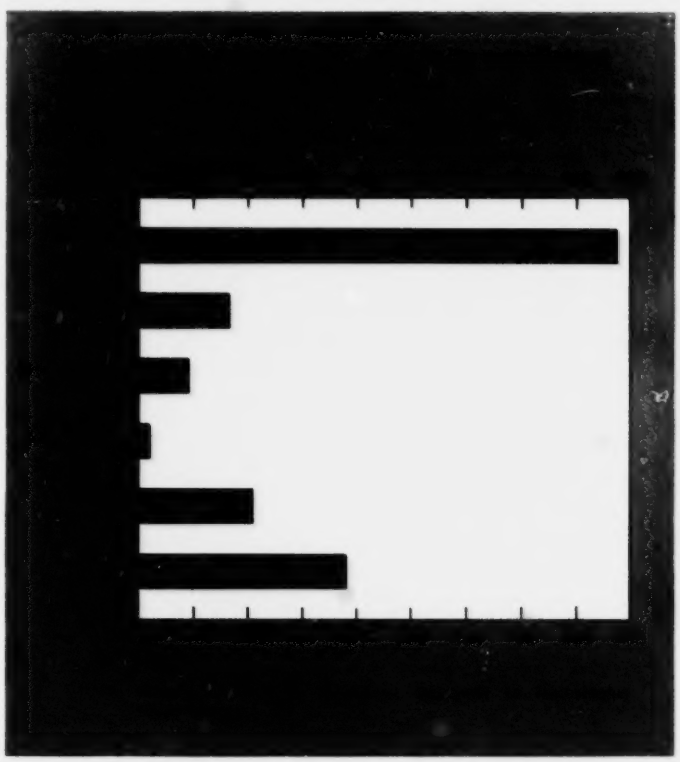
[53]Mintzes and Tash, *op. cit.*

[54]National Science Foundation, *Science and Engineering Doctorates: 1960-82* (NSF 83-328) (Washington, D.C., 1983), and *Grund-und Strukturdaten 1983/84*, *op. cit.*

[55]National Science Foundation, *Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook* (NSF 86-305)(Washington, D.C., 1986).

[56]Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT), *Bundesbericht*, *op. cit.*



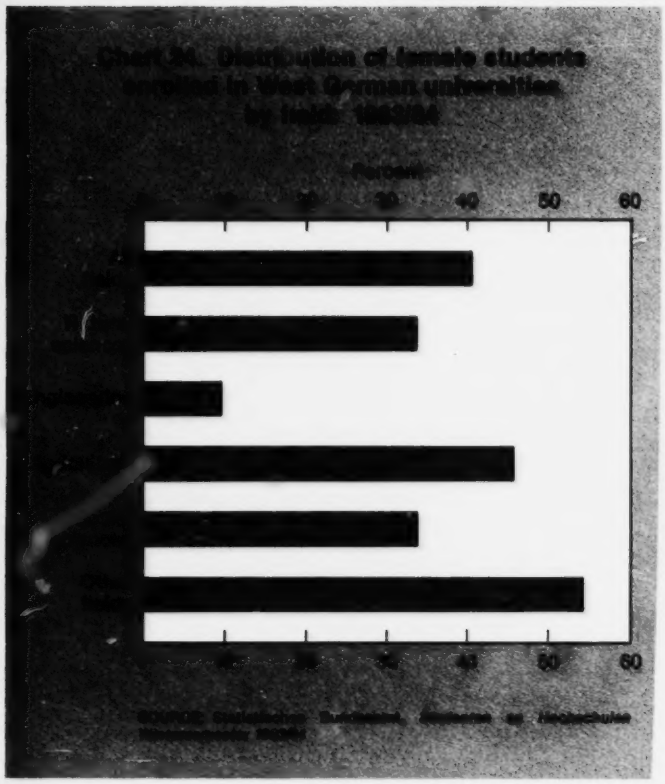


Enrollment data for West Germany demonstrate the continuing importance placed by university students on natural S/E fields (chart 23) and can be used as indicators of future trends since field concentrations have remained fairly stable. In 1983/84 about 20 percent of all West German students were enrolled in natural science fields and about 11 percent in engineering. Not all of these students will graduate, but it is likely that West Germany will be able to sustain its production of scientists and engineers at present or higher levels throughout the 1980's.

s/e training of women and foreign students

Data on university student demographic characteristics indicate that in 1983/84 almost a third of all students enrolled in natural sciences in West Germany were female (chart 24). Agriculture has a higher-than-average percent of female students (46 percent), but only 10 percent of students enrolled in engineering were women. Data on foreign-student enrollment in West German universities show that the highest concentration of foreign students is in the field of engineering (chart 25). In 1983/84 almost 10 percent of all engineering students in West Germany were foreign, compared with an average of 6 percent for all fields combined. Since students do not have to declare a major upon entering a university, similar enrollment data are not available for the United States except for engineering. Such data showed that for engineering, women represented 16 percent and foreign nationals constituted 6 percent of full-time students enrolled at the U.S. undergraduate level in fall 1983.[57] West Germany has a relatively lower percentage of female students and a higher percent-

[57]Engineering Manpower Commission of the American Association of Engineering Societies, Inc., *Engineering and Technology Enrollments, Fall 1983* (New York, New York, 1984.)



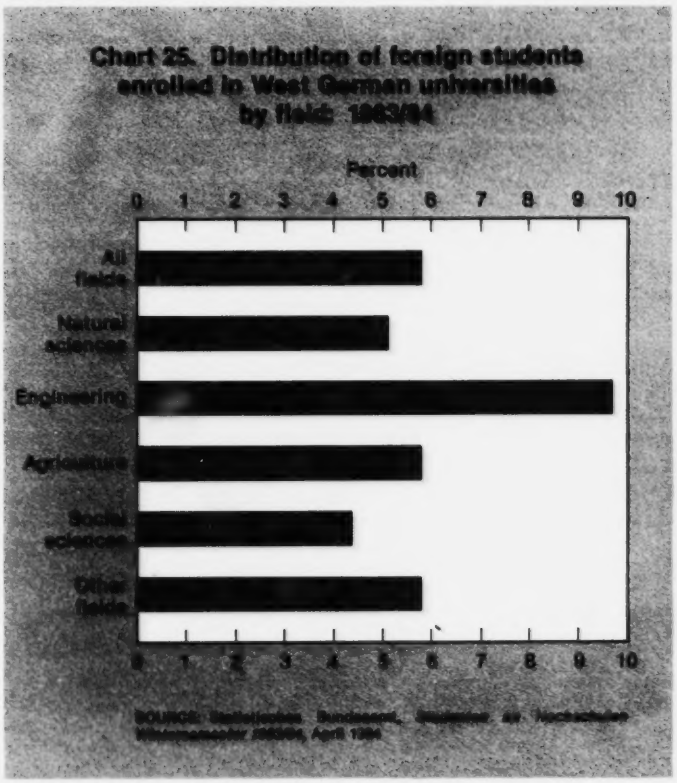


Chart 25. Distribution of foreign students enrolled in West German universities by field: 1983/84
Percent
0 1 2 3 4 5 6 7 8 9 10
All fields
Natural sciences
Engineering
Agriculture
Social sciences
Other fields

age of foreign students enrolled in undergraduate engineering studies than does the United States.

Table 5 shows that in both West Germany and the United States, women received a relatively high proportion of bachelor-level degrees in natural sciences and a relatively low proportion of degrees in engineering. The proportion of women in West Germany completing natural science degrees is almost identical to that for all fields, whereas in the United States it is lower than the female share of all fields combined. Women in the United States receive a greater proportion of degrees in both engineering and natural sciences, as well as total degrees, than in West Germany.

Table 5. Female proportion of first university degrees: 1983

Field	West Germany	United States
All fields	31%	51%
Natural sciences	30	39
Engineering	7	13

SOURCES: Statistisches Bundesamt and the National Science Foundation

s/t outputs and impacts

scientific literature

Scientific and technical publications are an important output of research, and publication counts are considered to be indicators of scientific activity. The following discussion is based on a large data set developed from the Science Citation Index (SCI) of the Institute for Scientific Information. Although there are some differences in national coverage, the SCI appears to provide generally well-balanced coverage for industrialized nations in the physical and biological sciences. This data set represents about 3,100 frequently cited or influential S/T journals.

Table 6 presents the West German proportion of the world's S/T articles by field based on this influential set of journals. It shows that in 1982, West German scientists and engineers authored 6.5 percent of the articles in all the fields covered. This proportion of scientific literature is twice as large as West Germany's share of the scientists and engineers engaged in research and development in the industrialized world. R&D scientists and engineers in West Germany represent about 3 percent of all such scientists and engineers found in industrialized nations.[58] U.S. scientists and engineers were responsible for 35 percent of the world's influential scientific literature and about 15 percent of the researchers. The highest West German share was in the field of physics (6.8 percent) followed by engineering and technology (6.6 percent), and mathematics (6.6 percent).

Table 6. West German and U.S. percentages of the world's science and technology articles[1] by field: 1981-82

Field	West Germany		United States	
	1981	1982	1981	1982
All fields ...	6.3	6.2	35.3	35.4
Biology	4.7	4.7	37.4	38.1
Biomedicine	6.2	6.3	39.5	39.8
Chemistry	6.5	6.2	19.6	20.9
Clinical medicine .	6.6	6.5	41.1	40.9
Earth and space sciences	4.4	4.3	42.0	41.9
Engineering and technology	6.7	6.6	37.7	37.7
Mathematics	8.7	6.6	35.9	37.0
Physics	6.6	6.8	30.0	27.4

[1]Based on articles, notes, and reviews in about 3,100 of the influential journals carried on the 1973 Science Citation Index Source Tapes of the Institute for Scientific Information. When an article is written by researchers from more than one country, the article is prorated across the countries involved.

SOURCE: Computer Horizons, Inc., unpublished data

The United States was responsible for a much higher proportion of S/T articles than any country in each of the major fields listed. The fields in which U.S. scientists and engineers authored the highest proportion of articles were earth and space sciences (41.9 percent), clinical medicine (40.9 percent), and biomedical research (39.8 percent).

From 1981 to 1982 the West German proportion of S/T articles was fairly steady but dropped slightly in many of these fields, with the largest decrease coming in mathematics. The fields of physics and biomedical research actually showed some slight gains.

[58]This estimate is based on data for all OECD countries and the Soviet Union. See Organisation for Economic Co-operation and Development, *Science and Technology Indicators* (Paris, France, 1984) and Robert Campbell, *Soviet R&D Statistics, 1970-83* (Washington, D.C., National Science Foundation, 1984).

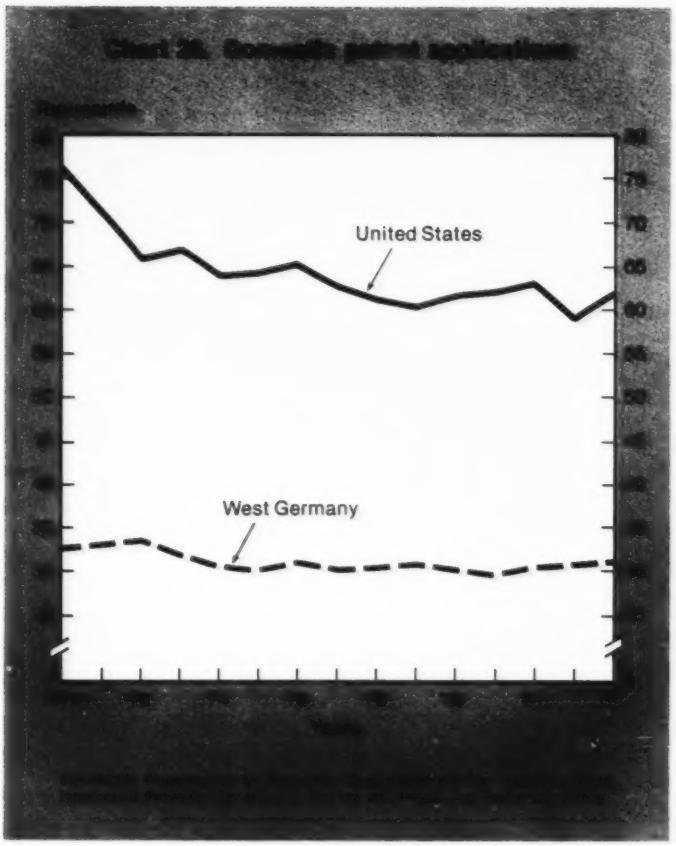
There were a number of subfields in 1982 in which West German articles represented at least 10 percent of the world's S/T literature. Table 7 shows these subfields in the order of the West German contribution to S/T literature.

Table 7. West German percent of world's science and technology articles, selected fields:[1] 1982

Subfield	Percent
Applied chemistry	15
Nuclear technology	14
Orthopedics	13
Obstetrics and gynecology	13
Microscopy	12
Metals and metallurgy	10
Materials science	10
Nuclear and particle physics	10

[1]Subfields in which West German articles represented 10 percent or more of the world's articles.

SOURCE: Computer Horizons, Inc., unpublished data



patent indicators

Patents represent one of the major outputs of research and development and innovation. Even though all new ideas or inventions are not patented, patent data have become accepted as being among the best measures of inventive activity. Although the perceived market potential and general economic conditions are important influences in the decision of whether and where to patent, studies have indicated that technological inventiveness is a driving factor in foreign patenting activity.[59]

During the seventies, domestic patent applications decreased in both West Germany and the United States (chart 26), indicating a probable decline in inventiveness. Intellectual property can be protected either by means of patenting or through other means such as the maintenance of trade secrets. Although an increased use of trade secrets may have affected these trends, the propensity to patent or protect via trade secrets differs among industries, firms, and inventions. Since domestic patenting has decreased across most product fields in the United States, it is thought that the decline in patenting actually represents a decrease in the production rate of inventions rather than being primarily attributable to the increased use of trade secrets.[60] In 1984, the number of patent applications by national inventors in West Germany was only 1 percent below the level at the beginning of the seventies. The U.S. level of domestic patent applications was 19 percent lower than in 1970. Recent patent application data presents a more optimistic picture. Domestic patenting in West Germany shows an upturn, and the decline in U.S. applications appears to have been reversed. From 1981 to 1984, domestic patenting increased 9 percent in West Germany compared with a 1-percent decline in the United States.

The most important or potentially profitable inventions are often patented abroad. U.S. inventors have been very successful in patenting their inventions in West Germany (chart 27). In 1970, almost 47 percent of all foreign-origin patents granted there went to U.S. inventors. This proportion dropped substantially during the midseventies, but since then has been holding fairly steady and was 29 percent in 1984.

During the sixties and up to the midseventies, West Germany patented more inventions in the United States than any other foreign country. In 1970, scientists and engineers from that country were granted over one-fourth of all foreign-origin patents in the United States and 7 percent of the total. The number of U.S. patents granted to West German inventors rose over 40 percent from 1970 to

[59]Keith Pavitt and Luc Soete, "Innovative Activities and Export Shares: Some Comparisons between Industries and Countries," in Keith Pavitt (ed.) *Technical Innovation and British Economic Performance* (London: MacMillan, 1980); and Luc Soete and Sally M.E. Wyatt, "Domestic and Foreign Patenting in the United States and the EEC Towards the Development of an Internationally Comparable Science and Technology Output Indicator," Workshop on Patent and Innovation Statistics (Paris, France: Organisation for Economic Co-operation and Development, 1982).

[60]National Science Board, *Science Indicators—1982, op. cit.*, p. 13.

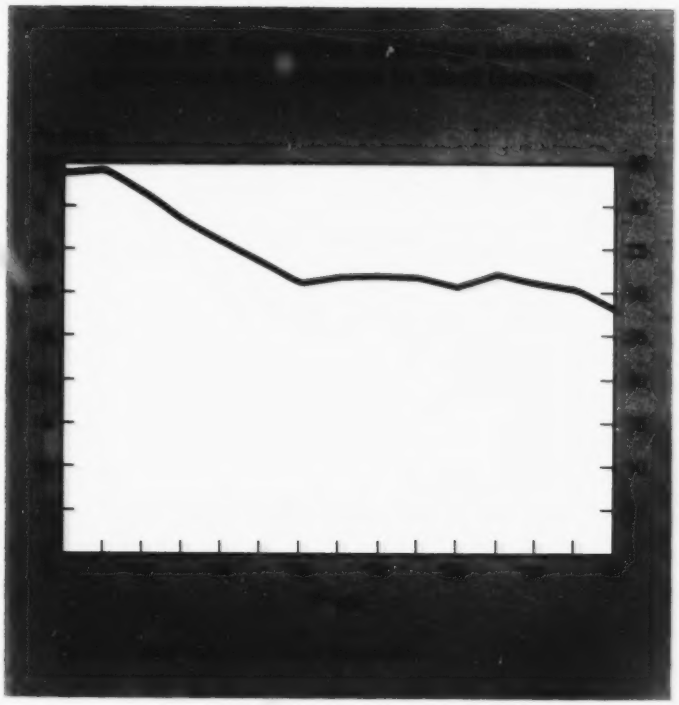


Table 8. U.S. patent areas with high-level West German activity[1]

Product group	West German percent of U.S. patents in 1983
Railroad equipment	18
Special industrial machinery except metal working machinery	16
Industrial organic chemistry	14
Agricultural chemicals	13
Ordnance except missiles	11
Soaps, perfumes, cosmetics	10
Shipbuilding and repair	10
Construction and mining equipment	9
Farm and garden machinery	8
Guided missiles and space vehicles and parts	7

[1]Those product groups in which West German inventors were granted the highest proportion of U.S. patents of any foreign country.

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *Patent Trends in the United States and Other Countries, Fractional Count Report 1963-83*, 1984

1984, and U.S. domestic patenting declined 30 percent through 1983 before increasing substantially in 1984. Thus, although the West German share of foreign-origin patents declined slightly to 22 percent, the proportion of total U.S. patents granted to West German scientists and engineers increased to 9 percent in 1984.

Patenting activity in the United States with respect to product field is highly concentrated. Over 60 percent of U.S. patents granted to West German inventors are in machinery and chemical technologies, and about 54 percent of U.S. domestic patents are in these same areas. West German inventions were more highly concentrated in nonelectrical equipment (27 percent) than those of domestic U.S. inventions (22 percent). This was true for the chemicals and allied products group as well, which represented one-fifth of West German-origin patents compared with 15 percent of those patents granted to U.S. inventors. The United States had a higher percentage of its patents in electrical equipment than did West Germany—17 percent versus 14 percent.

In 1975, the United States granted more patents to Japanese inventors than to West Germans. By noting the nationality of U.S. patent applicants according to product group of invention, one can discern the relative technological competitiveness of foreign countries. By 1983, Japan had become the leading foreign patent country in the United States in all major product groups—many of which were areas of previous German strength. This was true for chemicals and allied products, machinery—both electrical and nonelectrical, professional and scientific instruments, aircraft and parts, and motor vehicles.

In 1983, more West Germans were granted patents in the United States in a number of specific product groups than from any other foreign country. Table 8 lists those product groups in the order of their percentage of total U.S. patents in 1983.

Although Japan had assumed the foreign leadership in percentage of patents granted in the United States, West Germany received a relatively high proportion in 1983 in the following areas: Motor vehicles and parts, 14 percent; aircraft and parts, 14 percent; and engines and turbines, 13 percent.

Because the cost and effort involved in applying for a patent in a foreign country act as a quality screen, external patents are thought to have more technical or commercial value than the average domestic patent. Since companies generally will seek patent protection before exploiting their inventions via foreign licensing or foreign trade, foreign patenting can also be an indication of foreign-market interest.

An examination of external patenting by OECD countries showed that the United States and Germany had the highest shares of all OECD external patents. The United States declined from 35 percent in 1970 to 32 percent in 1982, but the West German share was steady at about 20 percent.[61]

External or foreign patent applications by both U.S. and West German inventors

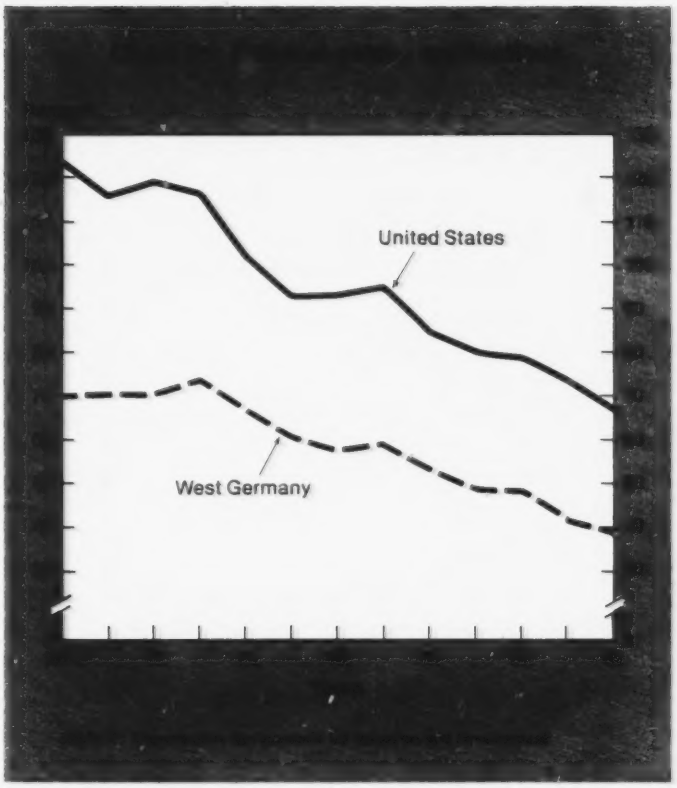
[61]Organisation for Economic Co-operation and Development, *OECD Science and Technology Indicators II*, Annex (Paris, France, 1985).

decreased 31 percent and 23 percent, respectively, between 1970 and 1978 (chart 28). Obviously not all patent applications result in patent grants, but the number of foreign patents granted probably also declined unless the application-to-grant success rates drastically increased.[62]

Two significant mechanisms for international patenting have become available since 1978. The Munich Convention of October 5, 1973, known also as the European Patenting Convention (EPC), and the International Patent Co-operation Treaty (PCT), greatly simplify the filing of patent applications for the same invention in more than one country. This has greatly increased the number of external patents. When these EPC and PCI patent filings are added to the World Intellectual Property Organization (WIPO) data that now show national filings, the resulting trends in external patenting are quite different; between 1978 and 1982 the number of U.S. external patent applications increased 35 percent reaching their 1970 level, and the West German external patent applications increased 33 percent to about 80 thousand in 1982. Because these international mechanisms offer the possibility of patent protection in a broader array of countries at a low marginal cost, the overall effect is an inflation in external patenting which may or may not correspond closely with an increase in inventiveness. Nonetheless, the increase in external patent protection certainly enhances the potential industrial competitiveness of a nation. It should be noted that the increase in external patenting via international patenting mechanisms does not affect significantly the domestic patenting trends and conclusions based on trends in West German patenting in the United States which were discussed earlier. For instance in 1983, the use of international patent mechanisms increased domestic patenting only by 2 percent in West Germany and only 0.4 percent in the United States.[63]

[62]These data are from the World Intellectual Property Organization, which collects and publishes national patent data from most of the countries in the world. Unfortunately only patent application data are available for world totals.

[63]Based on data in an unpublished OECD working paper on the technological position of OECD members presented for discussion at an October 1984 meeting.



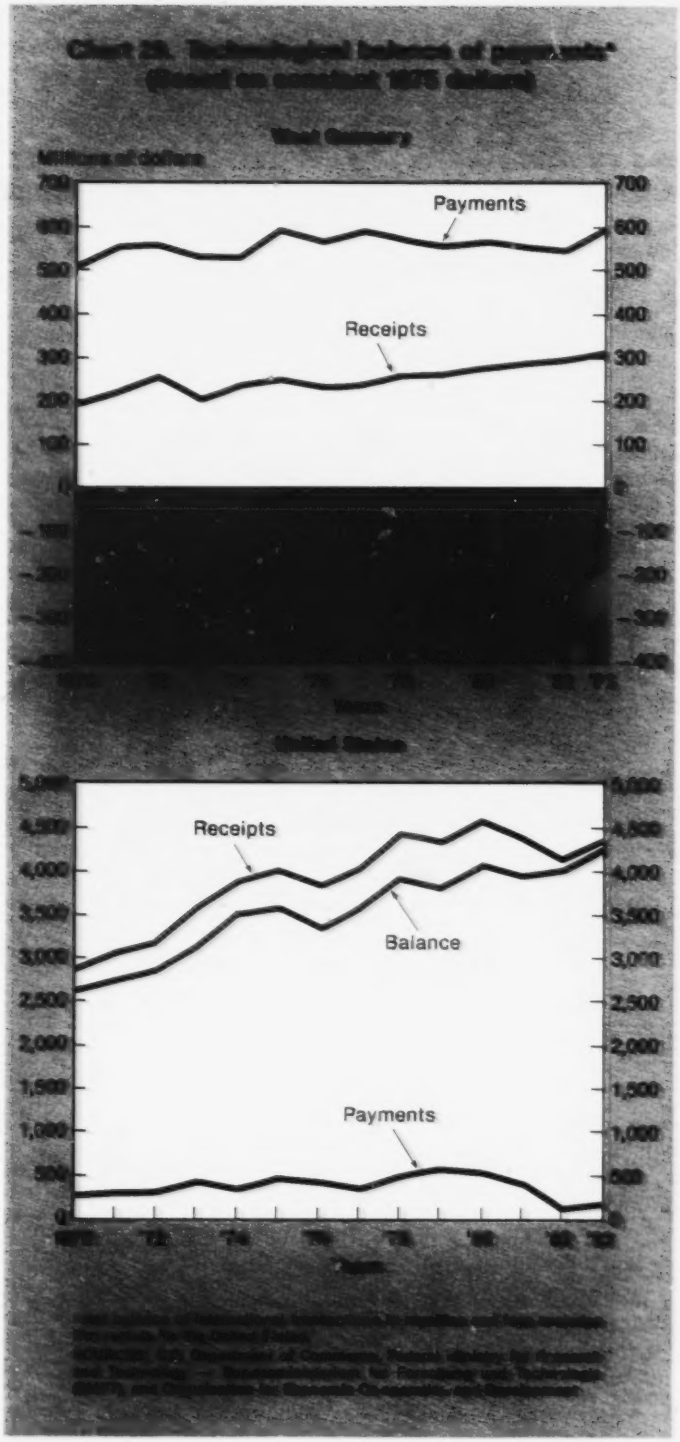
royalties and fees

Data on international transactions in royalties and fees are often used as indicators of technology transfer. Royalties and license fees are payments for the use of intellectual property such as patents, inventions or processes, copyrights, etc. It should be stressed that for several reasons these are only a rough and partial indicator of the level of transfer. They are only partial measures because technology can be transferred across national borders as exported or imported goods or services. Payments are usually spread over time rather than paid in lump sums and therefore data on any given year reflect returns on previous agreements as well as contracts in that year. Nonetheless, royalties and fees data do provide some information on the flow and direction of technology.[64]

Data on international receipts and payments for West Germany and the United States demonstrate that the major difference between these two countries is that West Germany is a net importer and the United States a net exporter of technical know-how (chart 29). In 1983, U.S. receipts for royalties and fees were over 30 times the payments; in West Germany, payments were almost twice the receipts. U.S. receipts increased almost 49 percent in real terms from 1970 to 1983, reaching 4.4 billion constant dollars. West German receipts rose 61 percent over the same period and payments were only 18 percent higher. In fact, between 1975 and 1982 West German payments declined 8 percent. As a result, the West German balance, although still negative, has improved and registered a deficit of 284 million constant dollars in 1983. Over half of the West German purchases of technical know-how through royalties and fees are from the United States.[65]

[64]For a more complete discussion of the limitation and meaning of these data, see Jennifer Sue Bond, "US International Transactions in Royalties and Fees—Trends and their Interpretation," a paper presented at an OECD Workshop, December 1981.

[65]Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT), *op. cit.*



technology trade

Trade in high technology products represents another mode of technology transfer. Although it is difficult to determine the precise amount of technology transferred, it is undeniable that international trade is a major channel through which technology flows and that such trade has an increasingly important economic impact.

West Germany maintained a negative balance of trade in technology-intensive[66] products with the United States throughout the sixties, but this deficit worsened considerably in the seventies and eighties. In 1970, the deficit was $0.5 billion, but by 1981, it had reached $2.8 billion (chart 30). Exports to the United States increased in 1983 and 1984, improving the West German trade balance to a negative $1.5 billion. West Germany also began to run a negative balance of trade in technology-intensive products with Japan in 1969. By 1984, West Germany's deficit with Japan had reached $2.4 billion, greater than its deficit with the United States. West Germany has maintained a positive balance of trade, however, with its other partners. In 1984, for example, West Germany had a $1.6 billion surplus of technology-intensive trade with Italy, $1.8 billion positive balance with France, and $0.9 billion surplus with the United Kingdom. West Germany registered an overall positive trade balance of $10.6 billion in technology-intensive products in 1984.

Trade with the United States has been influenced by the dollar exchange rate and strong U.S. economic recovery.[67] In 1984, West Germany had a positive balance with the United States in agricultural chemicals, engines and turbines, radio and TV receivers, and professional and scientific instruments (table 9).

West Germany's largest deficit with the United States is in office computers and accounting machinery ($1.0 billion). It has a somewhat smaller deficit in electrical machinery, communications equipment and electronic components, and aircraft and parts, even though its overall trade balance was positive in these three product fields. (See table B-37.) West Germany also registered a deficit in world trade in office machines and radio and TV receiving equipment.

Between 1970 and 1984, both the U.S. and West German world export shares declined in many of the product groups

[66]There is no universally accepted definition of high-technology products or technology-intensive products. The definition used here is one that was adopted by the OECD: Technology-intensive products are those products for which R&D expenditures exceed 2.36 percent of sales. See table 6 for a list of the product fields included.

[67]U.S. Department of Commerce, *U.S. Trade Performance in 1983 and Outlook* (Washington, D.C., June 1984.)

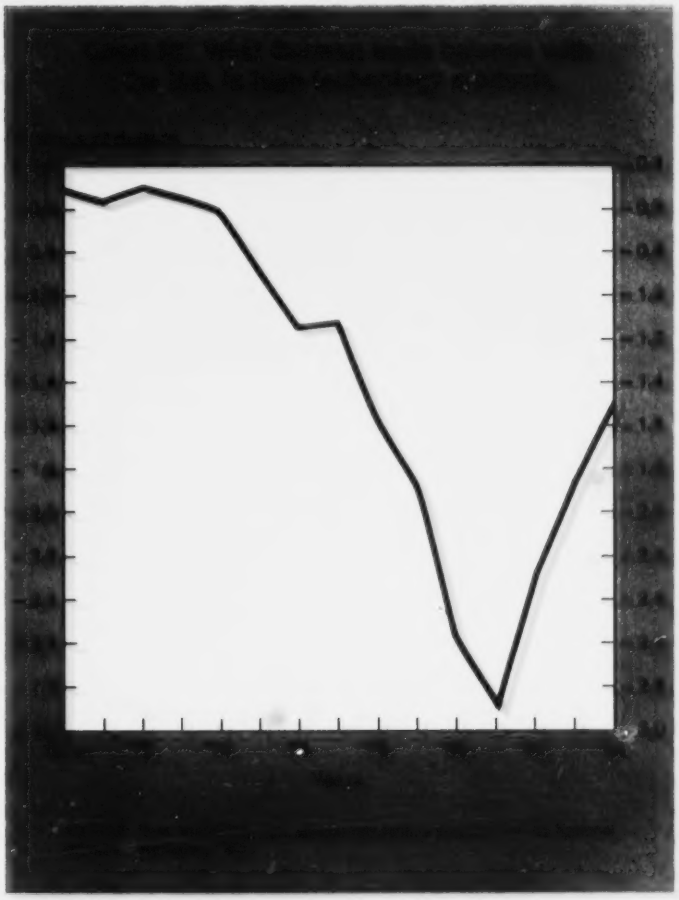


Table 9. West German trade in selected high technology products[1] with the United States: 1984

[Dollars in millions]

Product group	Exports	Imports	Balance
Total	$2,968.9	$4,500.3	$-1,531.4
Aircraft and parts	119.5	270.3	-150.7
Office computing and accounting machines	341.1	1,361.0	-1,019.9
Electrical transmission and distribution equipment	542.3	880.7	-338.4
Communication equipment and electronic components	180.1	568.5	-388.4
Professional and scientific instruments	666.1	435.2	230.9
Drugs	135.0	139.9	-4.9
Plastic materials and synthetics	305.5	344.2	-38.7
Engines and turbines	395.6	126.0	269.5
Agricultural chemicals	44.5	24.1	20.4
Industrial inorganic chemicals	220.3	344.8	-124.5
Radio and TV receiving equipment	19.0	5.6	13.3

[1]Technology-intensive products are those defined here as those for which R&D expenditures exceed 2.36 percent of sales.

SOURCE: Special tabulations prepared for the Division of Science Resources Studies, National Science Foundation, by Data Resources, Inc., 1986.

as can be seen in table 10. West Germany increased its export share only in aircraft and parts, which rose from 3.4 percent in 1970 to 15.2 percent in 1984. Its export share dropped 5.2 percentage points in drugs between 1970 and 1982, but subsequently recovered somewhat and was 15.8 percent in 1984. West Germany's highest export share was in plastics and synthetic materials. This share has remained steady at about 21 percent. The United States also experienced declines in many of the groups examined, but produced a large increase in its share of agricultural chemicals; the U.S. share rose from 19.7 percent in 1970 to 33.7 percent in 1984. The United States experienced smaller increases in its export shares in the following product groups: Engines and turbines, electrical trans-

Table 10. Percent distribution of world[1] export shares in technology-intensive product groups:[2] 1970, 1982, and 1984

Product group	West Germany			United States		
	1970	1982	1984	1970	1982	1984
Total	16.8	15.5	14.5	27.0	24.7	25.2
Aircraft and parts	3.4	11.6	15.2	60.7	52.7	45.1
Office computing and accounting machines	15.1	11.5	9.2	37.5	38.0	35.5
Electrical transmission and distribution equipment	22.5	19.1	17.3	21.9	22.9	23.8
Communications equipment and electronic components	15.2	12.5	10.4	27.7	25.9	26.5
Professional and scientific instruments	20.1	15.7	15.3	21.8	16.7	13.7
Drugs	19.5	14.3	15.8	16.5	15.9	19.6
Plastic materials and synthetics	22.3	21.0	21.4	17.2	15.0	14.4
Engines and turbines	18.1	16.9	16.4	27.7	30.5	29.9
Agricultural chemicals	17.3	12.5	13.0	19.4	28.6	33.7
Industrial inorganic chemicals	17.3	15.4	15.0	23.1	20.6	23.9
Radio and TV receiving equipment	12.4	9.5	8.2	6.4	2.1	.5

[1]World share is based on 24 reporting countries.

[2]Technology-intensive products are those defined here as those for which R&D expenditures exceed 2.36 percent of sales.

SOURCE: Special tabulations prepared for the Division of Science Resources Studies, National Science Foundation, by Data Resources, Inc., 1986.

mission equipment, and drugs. Considering all of these groups together, West Germany's export share dropped from 16.8 percent in 1970 to 14.5 percent in 1984. The U.S. share was higher, but also declined—from 27 percent in 1970 to 25.2 percent in 1984.

During the same period, 1970-84, Japan increased its export share in these product groups by 9 percentage points, surpassing the West German share. Japan's export share reached 20 percent in 1984, and was second only to the United States. France also experienced a slight increase in its export share in these product fields throughout the sixties and maintained a level of about 8 percent in the eighties. This was still below the share of the United States, Japan, and West Germany.[68]

In conclusion, West Germany has increased its S/E resources since the seventies, with a slowdown of growth occurring in the eighties. In terms of science, West Germany's share of a set of the world's influential scientific and technical literature appears to be fairly steady and even increased slightly in the fields of physics and biomedicine. Its competitive edge in many technological areas on the other hand seems to be decreasing. The West German share of world exports in many technology-intensive product groups has declined and West Germany has been succeeded by Japan as the foreign leader in U.S. patenting activity in most product groups.

[68]Based on data in special tabulations provided to the Division of Science Resources Studies, National Science Foundation, by Data Resources, Inc., 1986.

appendixes

a. technical notes

b. statistical tables

appendix a

technical notes

Differences in definitions, concepts, and data collection and reporting practices make precise cross-country comparisons difficult. Much has been done by the Organisation for Economic Co-operation and Development (OECD), however, to institute uniform definitions and standards. The West German data presented here generally reflect the definitions as outlined in the OECD manual, commonly referred to as the Frascati Manual.[1] The data presented by the West German Government in documents such as the *Bundesbericht Forschung 1984* differ somewhat from those it reports to the OECD: research and development (R&D) expenditures reported in its national data are higher than those reported in OECD. For example, West German total R&D expenditures in 1983 as reported in the national data were about 46.8 billion deutsche marks (DM), compared with the DM43.0 billion reported to OECD. The differences arise, in part, because the OECD definitions require data to be reported on the basis of the institutions that perform research and development, i.e., the data are performer-based. The *national* data are collected from agencies that fund research and development, i.e., the data are source-based and include R&D funds that are provided to those institutions whose primary function is other than research. The main difference, however, is that the national data include West German funds for research and development performed by both international organizations and German institutions abroad. Such expenditures are not included in the U.S. data and thus this report utilizes principally the data provided to OECD since they more closely approximate those of the United States.

Some data presented in this report are of necessity based on national data. These include R&D funds disaggregated by the Federal and State Governments (Bund and Laender), or by ministries, as well as Government targets for R&D expenditures. The data on R&D-to-sales ratios are based on national industrial data because sales data are available only on the basis of the national industrial categories. There are various measures of R&D intensity that are frequently used by analysts (e.g., R&D-to-sales, R&D-to-value added, etc.). R&D-to-sales is used in this report because data are available by industries for both the United States and West Germany.

In the interest of presenting as complete a profile of West German science and technology (S/T) efforts as possible, data on basic research and on research and development in the higher education sectors are presented. It should be noted that these data are more problematic and are less reliable than other R&D expenditure data. Therefore consideration should be given only to trends and to major changes and differences in data for this sector. Although R&D expenditures in the humanities are generally included in West German R&D data they represent only about 1 percent to 2 percent of the national total. Estimates have been made to exclude these figures for the field distributions in the higher education sector data.

Fully satisfactory R&D deflators (which would correct the effects of inflation on R&D activities) and R&D exchange rates have not yet been developed. Use of current exchange rates results in figures that are heavily influenced by the relative strengths of national currencies. To provide more accurate comparisons with U.S. resources, purchasing-power parities rather than

[1]Organisation for Economic Co-operation and Development, *The Measurement of Scientific and Technical Activities*, 1981, commonly called the Frascati Manual, which outlines the definitions, survey procedures, etc. (Paris, France, 1981).

current exchange rates are used unless otherwise specified. Exchange rates reflect comparable purchasing power between countries and have been calculated at a general level, referring to the economy as a whole. Thus they indicate the purchasing power for R&D resources only broadly. The purchasing power parities have been taken from OECD national accounts data. They are based on direct price observations made in studies developed under the auspices of Eurostat and the United Nations International Comparisons Project. Constant-dollar figures are based on the implicit gross domestic product (GDP) deflator derived from the OECD National Accounts data bank. The base year is 1975.

appendix b

statistical tables

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Table B-1. National expenditures for the performance of research and development: 1970-85

Year	Constant 1975 dollars in millions[1]	
	West Germany	United States
1970	$6,348	$35,800
1971	6,973	34,644
1972	7,314	35,596
1973	7,203	36,569
1974	7,443	35,722
1975	7,656	35,213
1976	7,816	36,809
1977	8,017	38,199
1978	8,601	40,108
1979	9,614	41,934
1980	[2]9,891	43,789
1981	10,066	46,067
1982	10,351	47,731
1983 (prel.)	10,462	50,972
1984 (est.)	[2]10,606	54,042
1985 (est.)	[2]11,108	58,182

[1]Based on OECD deflators and purchasing power parities.

[2]NSF estimate.

NOTE: West German data for 1984-85 are NSF estimates based on preliminary national figures.

SOURCES: Organisation for Economic Co-operation and Development, National Science Foundation, and Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT)

Table B-2. National expenditures for the performance of research and development as a percent of the gross national product: 1970-85

Year	West Germany	United States
1970	2.1%	2.6%
1971	2.2	2.4
1972	2.2	2.3
1973	2.1	2.3
1974	2.1	2.2
1975	2.2	2.2
1976	2.2	2.2
1977	2.1	2.1
1978	2.2	2.1
1979	2.4	2.2
1980	2.4	2.3
1981	2.5	2.4
1982	2.6	2.5
1983 (prel.)	2.5	2.6
1984 (est.)	2.5	2.6
1985 (est.)	2.6	2.7

NOTE: West German data for 1983-85 are NSF estimates based on preliminary national figures.

SOURCES: Organisation for Economic Co-operation and Development, National Science Foundation, and Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT)

Table B-3. Estimated ratio of nondefense research and development (R&D) expenditures[1] to gross national product: 1970-85

Year	West Germany	United States
1970	1.9%	1.7%
1971	2.0	1.6
1972	2.1	1.6
1973	1.9	1.6
1974	2.0	1.6
1975	2.1	1.6
1976	2.0	1.6
1977	2.0	1.6
1978	2.1	1.6
1979	2.3	1.7
1980	2.3	1.8
1981	2.4	1.8
1982	2.5	1.9
1983 (prel.)	2.4	1.9
1984 (est.)	2.4	1.8
1985 (est.)	2.5	1.9

[1]National R&D expenditures excluding Government funds for defense.

NOTE: West German data for 1983-85 are NSF estimates based on preliminary national figures.

SOURCES: Organisation for Economic Co-operation and Development and the National Science Foundation

Table B-4. National research and development (R&D) by source of funding: 1970-83

[Constant 1975 dollars in millions]

Year	West Germany			
	Government financed	As percent of total R&D	Industry financed	As percent of total R&D
1970	$2,881	45.4	$3,388	53.4
1971	3,244	46.5	3,626	52.0
1972	3,611	49.4	3,580	49.0
1973	3,583	49.7	3,504	48.7
1974	3,723	50.0	3,580	48.1
1975	3,633	47.4	3,838	50.1
1976	3,667	46.9	3,955	50.6
1977	3,542	44.2	4,236	52.8
1978	3,842	44.7	4,458	51.8
1979	4,084	42.5	5,328	55.4
1980	NA	NA	NA	NA
1981	4,191	41.6	5,738	57.0
1982	4,361	42.1	5,890	56.9
1983	4,282	40.9	6,083	58.1
	United States			
1970	20,400	57.0	14,307	40.0
1971	19,434	56.1	14,055	40.6
1972	19,760	55.5	14,638	41.1
1973	19,523	53.4	15,825	43.3
1974	18,315	51.3	16,172	45.3
1975	18,109	51.4	15,820	44.9
1976	18,787	51.0	16,692	45.3
1977	19,280	50.5	17,526	45.9
1978	19,899	49.6	18,708	46.6
1979	20,469	48.8	19,909	47.5
1980	20,595	47.1	21,616	49.4
1981	21,412	46.5	23,039	50.0
1982	21,971	46.0	24,111	50.5
1983	23,347	46.7	24,945	49.9

NOTE: NA - not available.

SOURCES: Organisation for Economic Co-operation and Development and the National Science Foundation

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Table B-5. Current expenditures for basic research: selected years

[Dollars in millions]

Year	Total	Percent of research and development[1]
	West Germany	
1973	$1,460	30
1975	1,710	26
1977	1,946	25
1979	2,261	21
1981	3,072	22
	United States	
1973	3,946	13
1975	4,608	13
1977	5,537	13
1979	7,257	13
1981	9,180	13

[1]Percent of current R&D expenditures.

SOURCES: Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT) and the National Science Foundation.

Table B-7. Current expenditures for applied research and development: selected years

[Dollars in millions]

Year	Applied research and development	As percent of total
	West Germany	
1973	$3,581	71
1975	4,830	74
1977	5,950	75
1979	7,792	71
1981	11,210	81
	United States	
1973	26,772	87
1975	30,605	87
1977	37,246	87
1979	47,676	87
1981	62,660	87

[1]Percent of current R&D expenditures.

SOURCES: Organisation for Economic Co-operation and Development and the National Science Foundation.

Table B-9. Ratio of research and development (R&D) scientists and engineers (S/E's) to labor force: 1970-84

Year	R&D S/E's (in thousands)	R&D S/E's to 1,000 labor force
	West Germany	
1970	82.5	3.1
1971	90.2	3.4
1972	96.0	3.6
1973	101.0	3.7
1974	102.5	3.9
1975	103.7	3.9
1976	104.5	4.0
1977	111.0	4.3
1978	NA	NA
1979	122.0	4.5
1980	NA	NA
1981	128.2	4.7
1982	129.0	4.7
1983	129.5	4.7
1984 (est.)	130.0	4.7
	United States	
1970	544.2	6.4
1971	523.8	6.1
1972	515.3	5.8
1973	514.8	5.6
1974	520.8	5.6
1975	527.7	5.5
1976	535.6	5.5
1977	561.0	5.6
1978	587.0	5.7
1979	614.8	5.8
1980	651.7	6.0
1981	683.7	6.2
1982	702.8	6.3
1983	722.9	6.4
1984 (est.)	750.7	6.5

NOTE: NA - not available.

SOURCES: Statistisches Bundesamt, Organisation for Economic Co-operation and Development, and the National Science Foundation.

B-6. Percent distribution of basic research expenditures[1] by performer: selected years

Year	Total	Government	Industry	Higher education
	West Germany			
1973	100	18	12	70
1975	100	19	12	69
1977	100	19	9	73
1979	100	25	15	59
1981	100	22	18	60
	United States			
1973	100	15	16	60
1975	100	16	16	59
1977	100	17	16	58
1979	100	15	16	60
1981	100	14	18	59

[1]Current expenditures.

NOTE: There is a break in the West German series between 1977 and 1979 because of increased coverage of the industrial sector. In the United States 9 percent of basic research is performed by private nonprofit organizations for all the years shown.

SOURCES: Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BFMT), Organisation for Economic Co-operation and Development, and the National Science Foundation.

Table B-8. Natural scientists[1] as a percent of the labor force: selected years

Year	Natural scientists (in thousands)	As percent of labor force	Engineers (in thousands)	As percent of labor force
	West Germany			
1970	161.0	0.6	414.0	1.5
1980	231.0	.9	390.0	1.5
	United States			
1970	594.0	.7	1,367.2	1.6
1980	870.0	.8	1,701.2	1.6

[1]Includes physical, mathematical, and life scientists.

SOURCE: National Science Foundation.

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Table B-10. Percent distribution of West German Federal R&D funding by agencies: selected years

Agencies	1975	1977	1979	1981	1982	1983	1984[1]	1985[1]
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total (DM in millions)	7,538	7,731	10,026	10,700	11,906	11,313	11,622	13,086
Total (constant 1975 dollars in millions)	$2,513	$2,408	$2,881	$2,808	$2,984	$2,753	$2,828	$3,050
BMFT[2]	52.0	52.3	54.2	55.1	57.7	57.3	57.5	54.6
BMBW[3]	11.5	10.2	7.9	8.0	7.7	8.8	8.6	7.7
BMWi[4]	6.6	5.5	9.5	11.9	10.6	8.5	8.3	10.1
BMVG[5]	19.8	21.4	18.5	14.6	14.2	16.5	17.0	19.4
Other	10.1	10.6	9.9	10.4	9.8	8.9	8.6	8.2

[1]Preliminary.

[2]BMFT - Federal Ministry for Research and Technology.

[3]BMBW - Federal Ministry for Education and Science.

[4]BMWi - Federal Ministry of Economics.

[5]BMVG - Federal Ministry for Defense.

SOURCE: Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT), *Bundesbericht Forschung 1984*, May 1984, and BMFT, *Statistische Informationen*, December 1985.

Table B-11. Percent distribution of public research and development by objectives: 1973, 1983, and 1984

Public objective	West Germany			United States		
	1973	1983	1984	1973	1983	1984
Total	100.0	100.0	100.0	100.0	100.0	100.0
Agriculture, forestry, and fisheries	1.9	2.5	2.4	2.2	2.3	2.1
Industrial development	7.7	12.0	11.6	.3	.3	.2
Energy	10.2	15.2	15.0	3.7	6.6	5.8
Transportation and telecommunications	1.0	1.1	1.1	3.4	2.3	2.5
Urban and rural planning	.5	1.1	1.1	.5	.1	.1
Environmental protection	.6	2.8	2.8	1.1	.5	.5
Health	3.3	3.2	3.2	9.9	11.5	11.3
Social development and services	3.7	2.4	2.4	2.8	1.1	1.2
Earth and atmosphere	1.6	1.9	11.4	1.9	1.5	1.4
Space	5.4	4.0	3.9	16.8	5.5	5.2
Defense	12.1	9.6	9.8	53.6	64.3	66.0
Advancement of knowledge[1]	52.0	44.1	44.4	3.9	3.8	3.9

[1]This category should not be equated with basic research. It includes research and development financed from general purpose grants provided to universities. In West Germany such general university R&D funds represented three-fourths of the advancement in knowledge category and constituted one third of all Government R&D funds. The difference in emphasis on this category by the United States and West Germany reflects differences in approaches to financing research and development.

SOURCE: Organisation for Economic Co-operation and Development, Special Tabulations, July 1985.

Table B-12. West German Federal projected research and development (R&D) funds for selected priority areas: 1983-87

[DM in millions]

Priority area	1983	1984	1985	1986	1987	Percent average annual change
Total Federal R&D	12,054.5	12,279.4	13,002.6	12,977.0	13,256.7	2.4
MPG, DFG, and FhG[1]	987.7	1,025.0	1,071.9	1,114.4	1,151.2	3.9
Basic research in natural science areas	745.8	806.3	845.4	993.1	1,079.0	9.7
Space R&D	762.4	757.6	800.3	851.7	882.9	3.7
Aviation R&D	355.5	389.1	486.5	476.7	440.8	5.5
Energy R&D	2,492.0	2,441.5	2,470.4	2,169.8	2,119.0	−4.0
Information technology[2]	519.6	533.4	412.2	383.5	391.4	−6.8
Microelectronics	175.0	177.5	50.0	.0	.0	− −
Health	478.9	522.5	557.4	572.7	589.5	5.3
Biotechnology	99.1	105.9	115.4	119.6	123.3	5.6
Basic physical technologies	91.6	95.9	99.6	107.6	114.6	5.8
Production technology	38.5	70.0	125.0	130.0	135.0	36.8
Innovation	818.6	838.4	998.9	1,113.3	1,239.5	10.9
Defense R&D	1,857.9	1,955.7	2,243.2	2,173.2	2,241.2	4.8

[1]MPG - Max-Planck Society for the Advancement of Science, DFG - German Research Society, and FhG - Fraunhofer Society for the Advancement of Applied Research.

[2]Excluding the microelectronics and optical communications technology programs, the information technology area would increase by 3.6 percent.

SOURCE: Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT)

Table B-13. West German Federal research and development (R&D) funds for selected priority areas: 1983

Priority area	Constant 1975 dollars in millions	Percent of total Federal research and development
Total Federal research and development	2,933.0	100.0
MPG, DFG, and FhG[1]	240.3	8.2
Basic research in natural science areas	181.5	6.2
Space R&D	185.5	6.3
Aviation R&D	86.5	2.9
Energy R&D	606.3	20.7
Information technology	126.4	4.3
Microelectronics	42.6	1.5
Health	116.5	4.0
Biotechnology	24.1	.8
Basic physical technologies	22.3	.8
Production technology	9.4	.3
Innovation	199.2	6.8
Defense R&D	452.0	15.4

[1]MPG - Max-Planck Society for the Advancement of Science, DFG - German Research Society, and FhG - Fraunhofer Society for the Advancement of Applied Research.

SOURCE: Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT)

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Table B-14. Institutes of the Max-Planck Society

Institute	Location
MPI for Aeronomy	Katlenburg-Lindan
MPI for Astronomy	Heidelberg
MPI for Chemistry	Mainz
MPI for Biophysical Chemistry	Goettingen
MPI for Iron Research	Dusseldorf
MPI for Solid State Research	Stuttgart
Fritz-Haber Institute for Physical Chemistry	Berlin
Gmelin Institute for Inorganic Chemistry	Frankfurt/Main
MPI for Nuclear Physics	Heidelberg
MPI for Coal Research	Mulheim/Ruhr
MPI for Mathematics	Bonn
MPI for Metals Research	Stuttgart
MPI for Meteorology	Hamburg
MPI for Physics and Astrophysics	Munich
MPI for Plasmaphysics	Garching bei Munchen
MPI for Polymer Research	Mainz
MPI for Quantum Optics	Garching near Munich
MPI for Radio-Astronomy	Bonn
MPI for Radiation Chemistry	Mulheim/Ruhr
MPI for Fluid Dynamics Research	Goettingen
MPI for Biochemistry	Martinsvied near Munich
MPI for Biology	Tubingen
MPI for Biophysics	Frankfurt/Main
MPI for Experimental Endocrinology	Hannover
MPI for Nutritional Physiology	Dortmund
MPI for Medical Research	Heidelberg
MPI for Neurological Research	Cologne
MPI for Physiological and Clinical Research	Bad Nauheim
Friedrich Miescher Laboratory for Biological Research	Tubingen
MPI for Molecular Genetics	Berlin
MPI for Brain Research	Frankfurt/Main
MPI for Immune Biology	Freiburg
Clinical Research Groups of the Medical Clinics of the University of Goettingen	Goettingen
Clinical Research Group for Coagulation and Thrombosis, University of Giessen	Giessen
Clinical Research Group for Multiple Sclerosis	Wurzburg
Clinical Research Group for Reproductive Medicine	Munster
MPI for Biological Cybernetics	Tubingen
MPI for Limnology	Plon
Matthaei Research Unit	Goettingen
MPI for Experimental Medicine	Goettingen
MPI for Psychiatry	Munich
MPI for Psycho-Linguistics	Nijmegen, Netherlands
Research Unit for Psychopathology	Munich
MPI for Systems Physiology	Dortmund
MPI for Behavioral Physiology	Seewiesen
MPI for Developmental Biology	Tubingen
MPI for Cell Biology	Ladenburg near Heidelberg
MPI for Plant Breeding Research	Cologne
Bibliotheka Hertziana (of Italian Art)	Rome, Italy
MPI for Educational Research	Berlin
MPI for Psychological Research	Munich
MPI for History	Goettingen
MPI for Patent Law	Munich
MPI for Foreign and International Private Law	Hamburg
MPI for International Law	Heidelberg
MPI for European History of Law	Frankfurt/Main
MPI for Social Law	Munich
MPI for Criminal Law	Freiburg

SOURCE: Robert Gerwin and Barbara Holtz, *The Max-Planck-Gesellschaft and Its Institutes*, Max-Planck Society—Max-Planck-Gesellschaft (MPG), 1984

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Table B-15. Special collaborative research programs supported by German Research Society (DFG) in 1985 by field

Research areas	University
Mathematics	
Theoretical mathematics	Bonn
Approximation and optimization in applied mathematics	Bonn
Geometry and analysis	Goettingen
Stochastic mathematical models	Goettingen
Physics	
Topospecific chemistry and spectroscopy of molecular systems	Bayreuth
Structure and dynamics of interfaces	Berlin (Fu)
Hypersensitive interactions	Berlin
Polarization and correlation in atomic shock complexes	Bielefeld/Munster
Plasma physics	Bocham
Structural and magnetic phase transition in alloys and compounds	Duisburg/Bochum
Solid-state spectroscopy	Frankfurt/Darmstadt
Atmospheric trace elements	Frankfurt/Mainz
Solid-state reactions	Goettingen/Clausthal
Theoretical and practical stellar astronomy	Heidelberg
Energy transfer in processes of atomic and molecular impact	Kaiserslautern
Physics and chemistry of interstellar molecule clouds	Cologne
Magnetic incidence and reorganization phenomena of metals	Cologne/Aachen
Microscopic and structure-related processes of atomic and molecular movement	Konstanz
Medium energy physics	Mainz
Elementary surface stimuli	Munich (Tu)
Ferro-electricity	Saarbrucken
Chemistry	
Oil technology and chemistry	Clausthal
Photochemistry with lasers	Goettingen
Chemistry physics of macro-molecules	Mainz
Characteristics of simple molecules-experimental investigations as indicated by quantum theory	Wuppertal
Organization of macromolecular systems	Freiburg
Heterogeneous systems under high pressure	Erlangen
Local particle movement	Hannover
Primary processes of bacterial photosynthesis	Munich (Tu)
Earth sciences	
Geo-scientific problems of arid regions	Berlin (Tu)
Oceanography	Hamburg
Survey and reconnaissance methods for coastal regions and oceans	Hanover
Voltage and voltage transformation in the eithosphere	Karlsruhe
The tropical sphere of the Atlantic	Kiel
Crystal structure and chemical bonds	Marburg
Satellite geodesy	Munich (Tu)
High precision navigation	Stuttgart
Engineering	
General and mechanical engineering	
Vortexes in aviation	Aachen
Wave focusing in a continuum	Aachen
Correlation of production and component characteristics of synthetic materials	Aachen
Utilization of process heat from high-temperature reactors	Aachen
Flexible hand tools in machine manufacturing	Aachen
Motor combustion	Aachen
Energy and raw material-saving manufacturing processes	Aachen
Construction models in machine manufacturing	Berlin (Tu)
Motor technology	Bochum
Fire resistance of construction materials	Braunschweig
Air traffic safety	Braunschweig
Surface technologies	Darmstadt
Transportation systems for conveyance of piece goods	Dartmund
Substance and energy transport in aerosols	Duisburg
Coal conversion	Essen
Machine noise and vibrations	Hannover
Heating installations	Hannover
Metallurgical tools	Hannover
Ship technology and construction	Hannover
Water and gas purification processes	Karlsruhe
High pressure combustion chambers	Karlsruhe
Silo construction	Karlsruhe
Artificial intelligence	Karlsruhe
Programming technology	Munich (Tu)
Reaction and exchange technology in dispersed two-phase systems	Munich (Tu)
Very large scale integration (VLSI)	Saarbrucken/Kaiserslautern
Thermodynamic and flux problems of aerospace propulsion	Stuttgart
Production technology	Stuttgart
Flexible production assembly	Stuttgart
Architecture, town planning, and civil engineering	
Coastal engineering	Hannover
Measuring mechanics of currents for construction purposes	Korsruhe
Natural and manmade drainage systems in the Alps and surrounding areas	Munich (Tu)
Far-extending surfaces for roofs	Stuttgart
Natural construction in architecture and nature	Stuttgart
Electronics	
Semi-conductor technology	Aachen
Life sciences	
Biology	
Characteristics of biological membranes	Aachen/Dusseldorf (with Juelich)
Regularities and control mechanisms of metabolism in ecological systems	Bayreuth
Structure, function and biosynthesis of peptides and proteins	Berlin (Tu)
Directed membrane processes	Berlin (Tu)
Biological absorption and processing of information	Bochum
Ion gradients that steer cellular functions	Bochum
Structure and function of membrane-stabile proteins	Darmstadt
Biological signal reactions	Freiburg
Foundations of cellular reciprocal action and signal transmission	Goettingen
Molecular biology of the cell	Cologne
Mechanisms of cellular communication	Konstanz
Cell energetics and differentiation	Marburg
Eco-physiology: evaluation of ecological signals	Marburg
Organization of the eukaryote genom	Munich (U)
Biological, chemical, and technical foundations of bioconversion	Munich (Tu)
Reception and processing of signals in vertebrate hearing systems	Munich (Tu)
Intra- and inter-cellular identification systems	Munster
Membranic transport-processes in cells	Osnabruck
Senses: adaption of structures and mechanisms	Regensburg
Membrane research	Saarbrucken

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Table B-15. Special collaborative research programs supported by German Research Society (DFG) in 1985 by field—Continued

Research areas	University
Chemical biology of micro-organisms	Tubingen
Agriculture, forestry, and veterinary medicine	
Patho-mechanisms of rheumatoid inflammation among humans and animals	Hannover (Ti-Ho)
Bioeconomic models of horticulture production	Hannover (U)
Experimental research on animals	Hannover (Ti-Ho)/Berlin (Fu)
Physiologic-nutritional quality in agricultural products	Hohenheim
Suitable forms of small agricultural holdings in West Africa	Hohenheim
Production technologies for cattle raising	Munich (Tu)
Medicine	
Artificial organs—models and replacements	Aachen
Experimental cancer chemotherapy	Aachen
Cardiology	Dusseldorf
Diabetic research	Dusseldorf
Pathological mechanisms of brain functions	Dusseldorf
Foundations of early detecting and assessment of cancer	Erlanger/Nurenberg
Experimental and clinical research into leukemia and tumors	Essen
Medical virology (origins and development of tumors)	Freiburg
Brain research and physiology of the senses	Freiburg
Clinical and experimental hepatology	Freiburg
Pathological mechanisms of viruses (virology)	Freiburg
Cardiology	Gottingen
Psychosomatic medicine, clinical psychology, and psychotherapy	Hamburg
Functions and defects of receptor systems	Hamburg/Lubeck
Cardiovascular system	Heidelberg
Psychiatric epidemiology	Heidelberg
Molecular cellular and immunological changes and defense mechanisms of malignant diseases	Heidelberg
Lymphatic system and experimental transplantation	Kiel
Factors of tumor formation	Mainz
Immunopathogenesis	Mainz
Tumor and endocrine: basic endocrinology research	Marburg
Basis and clinical importance of extra cellular limited proteolysis	Munich
Regulation and genetics of human immune response	Munich
Functional adaptation and differentiation of neuron systems	Munich
Leukemia research and immunology genetics	Tubingen
Neurobiological aspects of behavior and pathological deviations	Tubingen
Biosynthesis, secretion, metabolism and effects of polypephd and steroid hormones	Ulm
Physiology of the cell system	Ulm
Cytologic foundations of experimental biology	Wurzburg
Gene expressions in vertebrate cells	Wurzburg
Primary variability of molecular mechanisms of cancer genes	Wurzburg
Social sciences	
Processes of cultural and national identity in Africa	Bayreuth
Knowledge and society in the nineteenth century	Bochum
Information and coordination of economic activities	Bonn
Microanalytic foundations of social policies	Frankfurt/Mannheim
The world economy and international economic relations	Hamburg/Kiel
Administration during a period of change: differentiating processes	Konstanz
Governmental allocation policies in a free market system	Munich
Analysis of psychotherapeutic processes	Ulm
Linguistics	Konstanz
Electronic linguistic research	Saarbrucken

NOTE: These research areas are examples of areas of excellence within the universities. They could also be considered as possible areas for scientific cooperation by U.S. scientists and engineers.

SOURCE: German Research Society—Deutsche Forschungsgemeinschaft (DFG)

Table B-16. Funds for industrial research and development: 1970-83

[Constant 1975 dollars in millions]

Year	West Germany	United States
1970	$4,063.9	$24,749.3
1971	4,439.2	23,792.2
1972	4,485.9	24,440.0
1973	4,404.9	25,296.4
1974	4,515.2	24,877.2
1975	4,823.0	24,187.0
1976	4,951.5	25,468.9
1977	5,207.8	26,629.5
1978	5,568.5	27,753.3
1979	6,643.7	29,180.2
1980	[1]6,792.9	31,122.4
1981	6,875.6	33,211.5
1982	7,218.0	34,895.8
1983	7,299.3	36,369.9

[1]Estimate.

SOURCE: Organisation for Economic Co-operation and Development

Table B-17. Industrial research and development expenditures as a percent of gross national product: 1970-83

Year	West Germany	United States
1970	1.32	1.82
1971	1.40	1.70
1972	1.35	1.65
1973	1.28	1.60
1974	1.29	1.60
1975	1.41	1.56
1976	1.36	1.57
1977	1.40	1.55
1978	1.45	1.54
1979	1.66	1.58
1980	1.66	1.69
1981	1.70	1.75
1982	1.80	1.89
1983	1.80	1.90

SOURCE: Organisation for Economic Co-operation and Development

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Table B-18. Comparison of industrial research and development expenditures: 1981

[Dollars in millions]

Industry	West Germany		United States	
	Amount	Percent	Amount	Percent
Total	$10,825	100.0	$51,810	100.0
Chemicals and allied products	2,419	22.3	5,625	10.9
Machinery[1]	1,528	14.1	6,818	13.2
Electrical equipment	2,592	23.9	10,329	19.9
Aerospace	668	6.2	11,968	23.1
Professional and scientific instruments	210	1.9	3,614	7.0

[1]Includes computers.

SOURCES: Organisation for Economic Co-operation and Development and the National Science Foundation.

Table B-19. Comparison of company research and development funds in selected industries: 1981

[Dollars in millions]

Industry	West Germany		United States	
	Amount	Percent	Amount	Percent
Total	$8,846	100.0	$35,428	100.0
Chemicals and allied products	2,311	26.1	5,205	14.7
Machinery[1]	1,375	15.5	6,124	17.3
Electrical equipment	2,196	24.8	6,409	18.1
Aerospace	148	1.7	3,440	9.7
Professional and scientific instruments	186	2.1	2,978	8.4

[1]Includes computers.

SOURCES: Organisation for Economic Co-operation and Development and the National Science Foundation.

Table B-20. Research and development (R&D)-to-sales ratios: 1981

Industry	West Germany R&D-to-sales	United States R&D-to-sales
Total	2.8	3.1
Chemicals and allied products	4.6	3.6
Machinery[1]	3.1	4.9
Electrical equipment	7.3	6.8
Aerospace	23.8	16.0
Professional and scientific instruments	5.3	8.1

[1]Includes computers.

SOURCES: Helga Echterhoff-Severitt, *Forschung und Entwicklung (FuE) in der Wirtschaft 1981* and the National Science Foundation.

Table B-21. Research scientists and engineers (S/E's) by industry: 1981

Industry	West Germany		United States	
	Research S/E's	Percent	Research S/E's	Percent
Total	77,017	100.0	487,800	100.0
Chemicals and allied products	11,195	14.5	54,700	11.2
Machinery[1]	13,935	18.1	69,200	14.2
Electrical equipment	28,997	37.7	106,900	21.9
Aerospace	4,271	5.5	95,200	19.5
Professional and scientific instruments	1,613	2.1	34,700	7.1

[1]Includes computers.

SOURCES: Organisation for Economic Co-operation and Development and the National Science Foundation.

Table B-22. Research and development expenditures in the higher education sector: 1970-83

[Constant 1975 dollars in millions]

Year	West Germany	United States
1970	$1,278.5	$5,735.5
1971	1,503.4	[1]5,590.5
1972	1,574.3	5,528.3
1973	1,589.1	5,545.5
1974	1,570.9	5,265.4
1975	1,530.3	5,559.7
1976	1,521.0	5,738.3
1977	1,492.1	5,890.2
1978	1,604.2	6,189.2
1979	1,536.3	6,345.0
1980	[1]1,626.4	6,563.6
1981	1,695.9	6,825.6
1982	1,654.1	6,634.3
1983	1,654.5	6,716.6

[1]NSF estimate.

SOURCES: Organisation for Economic Co-operation and Development and the National Science Foundation.

Table B-23. Higher education research and development (R&D) expenditures as a percent of total R&D expenditures: 1970-83

Year	West Germany	United States
1970	20.1	16.0
1971	21.6	16.1
1972	21.5	15.5
1973	22.1	15.2
1974	21.1	14.7
1975	20.0	15.8
1976	19.5	15.6
1977	18.6	15.4
1978	18.7	15.4
1979	16.0	15.1
1980	16.4	15.0
1981	16.8	14.8
1982	16.0	13.9
1983	15.8	13.9

[1]NSF estimate.

SOURCE: Organisation for Economic Co-operation and Development.

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Table B-24. Higher education research and development (R&D) expenditures by field:[1] 1981

Field	West Germany		United States	
	Amount	Percent	Amount	Percent
Total	$3,949	100.0	$9,269	100.0
Natural sciences and engineering, total	3,484	88.2	8,751	94.4
Natural sciences	1,299	32.9	4,764	51.4
Engineering	828	21.0	1,612	17.4
Medical sciences	1,175	29.8	1,605	17.3
Agricultural sciences	181	4.6	771	8.3
Social sciences	464	11.8	518	5.6

[1]West German data have been adjusted by NSF to exclude R&D expenditures in the humanities.

SOURCES: Organisation for Economic Co-operation and Development and the National Science Foundation

Table B-25. Number of first university degrees granted: 1973-83

Year	All fields	Natural sciences[1]	Engineering	Agriculture	Social sciences
	West Germany				
1973	32,300	5,400	4,500	1,000	10,300
1974	33,600	5,900	5,100	1,000	10,500
1975	33,700	5,600	4,800	1,000	10,600
1976	36,500	5,700	5,700	1,000	10,800
1977	37,500	6,100	5,800	1,200	11,900
1978	39,800	6,400	6,500	1,300	13,300
1979	42,800	6,300	6,500	1,400	13,300
1980	46,300	6,500	6,700	1,700	14,100
1981	46,900	7,300	6,800	1,800	14,700
1982	50,600	8,100	7,100	1,900	14,700
1983	54,800	8,900	7,700	2,100	14,700
	United States				
1973	980,700	94,000	47,000	13,800	140,600
1974	1,008,700	101,000	43,500	15,100	145,400
1975	987,900	100,500	40,100	16,500	137,900
1976	997,500	102,300	39,100	18,300	132,500
1977	993,000	101,600	41,600	20,200	125,100
1978	997,200	99,200	47,400	21,000	120,500
1979	1,000,600	97,500	53,700	21,600	115,800
1980	1,010,800	96,800	59,200	21,100	114,800
1981	1,019,200	98,500	64,100	20,200	112,100
1982	1,036,600	102,300	67,800	19,200	112,800
1983	1,054,200	104,800	73,000	19,200	110,300

[1]Includes physical, mathematical, and biological sciences.

SOURCES: Statistisches Bundesamt, *Prufungen an Hochschulen 1983*, 1985, and the National Science Foundation

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Table B-26. Number of doctoral degrees granted: 1973-83

Year	All fields	Natural sciences[1]	Engineering	Agriculture	Social sciences
	West Germany				
1973	10,100	2,000	700	200	1,200
1974	10,700	2,400	900	300	1,400
1975	11,400	2,600	1,000	300	1,300
1976	11,500	2,700	1,000	300	1,300
1977	11,400	2,800	1,000	300	1,300
1978	11,800	2,600	1,000	300	1,300
1979	11,900	2,700	1,100	300	1,200
1980	11,200	2,700	1,000	300	1,200
1981	12,300	2,700	1,000	300	1,200
1982	13,000	2,600	1,000	400	1,300
1983	13,600	2,700	1,000	400	1,300
	United States				
1973	33,800	9,000	3,400	900	5,800
1974	33,000	8,500	3,100	800	5,900
1975	33,000	8,400	3,000	900	6,100
1976	32,900	8,100	2,800	800	6,200
1977	31,700	7,900	2,600	800	6,100
1978	30,900	7,700	2,400	900	6,100
1979	31,200	7,900	2,500	900	6,000
1980	31,300	7,900	2,500	900	5,900
1981	31,300	8,000	2,500	1,000	6,100
1982	31,000	8,200	2,600	1,000	5,800
1983	31,200	8,200	2,800	1,000	6,000

[1]Includes physical, mathematical, and biological sciences.

SOURCES: Statistisches Bundesamt, *Prufungen an Hochschulen 1983*, 1985, and the National Science Foundation

Table B-27. First university degrees per 100,000 population: selected years

Year	Natural sciences[1]	
	West Germany	United States
1973	8.8	44.4
1981	11.8	42.9
1982	13.1	44.1
1983	14.5	44.7
	Engineering	
1973	7.1	22.2
1981	11.0	27.9
1982	11.5	29.2
1983	12.5	31.1

[1]Includes physical, mathematical, and biological sciences.

SOURCES: Statistisches Bundesamt and the National Science Foundation

Table B-28. Doctoral degrees per 100,000 population: selected years

Year	Natural sciences	
	West Germany	United States
1973	3.2	4.2
1981	4.4	3.5
1982	4.2	3.5
1983	4.4	3.5
	Engineering	
1973	1.1	1.6
1981	1.6	1.1
1982	1.6	1.1
1983	1.6	1.2

[1]Includes physical, mathematical, and biological sciences.

SOURCES: Statistisches Bundesamt and the National Science Foundation

Table B-29. West German student enrollment distribution, winter semester: 1983/84

Field	Total students	Percent
All fields	873,172	100.0
Natural sciences	167,760	19.2
Engineering	95,286	10.9
Agriculture	21,781	2.5
Social sciences	206,938	23.7
Other fields	381,407	43.7

SOURCE: Statistisches Bundesamt, *Studenten an Hochschulen Wintersemester 1983/84*, April 1984

Table B-30. West German female student enrollment in universities, winter semester: 1983/84

Field	Total students	Female students	Percent female
All fields	873,172	351,920	40.3
Natural sciences	167,760	56,594	33.7
Engineering	95,286	9,155	9.6
Agriculture	21,781	9,929	45.6
Social sciences	206,938	69,938	33.8
Other fields	381,407	206,304	54.1

SOURCE: Statistisches Bundesamt, *Studenten an Hochschulen Wintersemester 1983/84*, April 1984

Table B-31. West German foreign student enrollment, winter semester: 1983/84

Field	Total students	Foreign students	Percent foreign
All fields	873,172	50,568	5.8
Natural sciences	167,760	8,596	5.1
Engineering	95,286	9,258	9.7
Agriculture	21,781	1,266	5.8
Social sciences	206,938	9,180	4.4
Other fields	381,407	22,268	5.8

SOURCE: Statistisches Bundesamt, *Studenten an Hochschulen Wintersemester 1983/84*, April 1984

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Table B-32. National patent applications: 1970-84

Year	Total	Domestic	Foreign
	West Germany		
1970	66,132	32,772	33,360
1971	65,756	32,874	32,882
1972	67,354	33,381	33,973
1973	66,223	31,909	34,314
1974	63,545	30,534	33,011
1975	60,095	30,198	29,897
1976	61,705	31,065	30,640
1977	60,401	30,247	30,154
1978	58,492	30,308	28,184
1979	55,184	30,879	24,305
1980	51,345	30,314	21,031
1981	46,579	29,841	16,738
1982	47,826	30,668	17,158
1983	47,103	31,658	15,445
1984	45,209	32,598	12,611
	United States		
1970	103,175	76,195	26,980
1971	104,729	71,089	33,640
1972	99,298	65,943	33,355
1973	104,079	66,935	37,144
1974	102,538	64,093	38,445
1975	101,014	64,445	36,569
1976	102,344	65,050	37,294
1977	100,931	62,863	38,068
1978	100,916	61,441	39,475
1979	100,494	60,635	39,959
1980	104,329	62,098	42,231
1981	106,413	62,404	44,009
1982	109,625	63,316	46,309
1983	103,703	59,390	44,313
1984	111,284	61,841	49,443

SOURCES: Organisation for Economic Co-operation and Development, World Intellectual Property Organization, and the U.S. Patent and Trademark Office

Table B-33. Patents granted in West Germany: 1970-84

Year	Total	Domestic patents granted	Foreign patents granted	Patents granted to United States	United States percent of foreign patents
1970	12,887	6,386	6,501	2,882	44.3
1971	18,149	8,295	9,854	4,393	44.6
1972	20,600	9,642	10,958	4,575	41.8
1973	23,934	11,191	12,743	4,949	38.8
1974	20,539	9,793	10,746	3,913	36.4
1975	18,290	9,077	9,213	3,140	34.1
1976	20,965	10,395	10,570	3,333	31.5
1977	21,749	10,815	10,934	3,488	31.9
1978	23,514	11,581	11,933	3,819	32.0
1979	22,534	10,895	11,639	3,713	31.9
1980	20,188	9,826	10,362	3,211	31.0
1981	13,429	6,537	6,892	2,229	32.3
1982	16,306	8,279	8,027	2,531	31.5
1983	20,913	10,709	10,204	3,141	30.8
1984	21,758	11,402	10,356	2,987	28.8

SOURCE: World Intellectual Property Organization

Table B-34. External patent applications by West Germany and the United States: 1970-82

Year	West Germany	United States
1970	70,137	123,724
1971	70,798	116,052
1972	70,636	119,984
1973	74,073	116,581
1974	67,335	102,711
1975	60,810	93,042
1976	58,310	93,356
1977	59,517	95,749
1978	53,657	85,352
1979	49,539	80,744
1980	48,650	79,078
1981	42,323	73,895
1982	39,816	67,197

SOURCE: Organisation for Economic Co-operation and Development

Table B-35. West German and U.S. technological balance of payments: 1970-83

(Constant 1975 dollars in millions)

Year	West German			United States		
	Receipts	Payments	Balance	Receipts	Payments	Balance
1970	198.4	509.6	−311.3	2,923.3	308.2	2,615.1
1971	218.6	553.7	−335.1	3,084.1	313.0	2,771.4
1972	257.3	555.2	−297.9	3,207.5	367.5	2,840.0
1973	212.6	538.9	−326.3	3,596.4	458.3	3,138.1
1974	240.8	535.0	−294.2	3,895.7	376.1	3,519.6
1975	252.3	597.6	−345.2	4,008.0	473.0	3,535.0
1976	235.6	565.1	−329.6	3,852.8	454.7	3,398.1
1977	242.3	590.2	−348.0	4,020.5	387.5	3,633.0
1978	257.2	576.6	−319.4	4,426.7	508.3	3,918.3
1979	258.9	561.0	−302.1	4,387.0	583.2	3,803.8
1980	278.6	572.8	−294.2	4,627.3	532.9	4,094.4
1981	287.3	562.5	−275.2	4,399.4	442.2	3,955.1
1982	299.3	551.8	−252.4	4,143.4	120.5	4,022.9
1983	319.5	603.7	−284.2	4,353.2	132.9	4,220.2

SOURCES: Organisation for Economic Co-operation and Development, Federal Ministry for Research and Technology—Bundesministerium fur Forschung und Technologie (BMFT), *Bundesbericht Forschung 1984*, 1984, and U.S. Department of Commerce

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Table B-36. West German trade with the United States in technology-intensive products:[1] 1970-84

[Dollars in millions]

Year	Exports to the United States	Imports from the United States	Balance with the United States
1970	$454	$957	$ − 503
1971	507	1,048	− 541
1972	606	1,101	− 495
1973	856	1,392	− 536
1974	1,032	1,627	− 595
1975	945	1,816	− 871
1976	982	2,120	− 1,138
1977	1,275	2,389	− 1,114
1978	1,711	3,292	− 1,581
1979	2,119	4,124	− 2,005
1980	2,181	4,695	− 2,514
1981	2,144	4,991	− 2,847
1982	2,122	4,386	− 2,264
1983	2,504	4,356	− 1,852
1984	2,969	4,500	− 1,531

[1]Technology-intensive products are defined here as those for which R&D expenditures exceed 2.36 percent of sales.

SOURCE: Special tabulations prepared for the Division of Science Resources Studies, National Science Foundation, by Data Resources, Inc., 1986.

Table B-37. West German trade in selected high technology products[1] with the United States and the world: 1984

[Dollars in millions]

Product group	Exports		Imports		Balance	
	United States	World[2]	United States	World[2]	United States	World[2]
Total	$2,968.9	$38,652.9	$4,500.3	$28,063.8	$ − 1,531.4	$10,589.1
Aircraft and parts	119.5	4,263.7	270.3	4,052.7	− 150.7	211.1
Office computing and accounting machines	341.1	3,637.1	1,361.0	4,275.0	− 1,019.9	− 637.9
Electrical transmission and distribution equipment	542.3	6,763.5	880.7	3,480.4	− 338.4	3,283.1
Communication equipment and electronic components	180.1	3,151.2	568.5	3,120.7	− 388.4	30.5
Professional and scientific instruments	666.1	3,879.6	435.2	2,448.2	230.9	1,431.5
Drugs	135.0	1,994.9	139.9	1,139.1	− 4.9	855.8
Plastic materials and synthetics	305.5	7,015.7	344.2	4,110.1	− 38.7	2,905.6
Engines and turbines	395.6	3,088.6	126.0	1,270.1	269.5	1,818.2
Agricultural chemicals	44.5	1,160.9	24.1	686.2	20.4	474.7
Industrial inorganic chemicals	220.3	2,444.7	344.8	1,958.1	− 124.5	486.6
Radio and TV receiving equipment	19.0	1,253.1	5.6	1,523.0	13.3	− 270.0

[1]Technology-intensive products are those defined here as those for which R&D expenditures exceed 2.36 percent of sales.

[2]World trade data is based on OECD Trade Series C reflecting information from 24 reporting countries and nearly 200 partner countries.

SOURCE: Special tabulations prepared for the Division of Science Resources Studies, National Science Foundation, by Data Resources, Inc., 1986.

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other science resources publications

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R&D Funds

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"Defense Major Factor Behind Expected 7% Real Increase in 1986 National R&D Expenditures"	85-331	-----
"9% Increase in Company-funded Research and Development Planned for 1986"	85-329	-----
"15% in Federal R&D Funds Proposed in 1986 Budget, Mostly for Defense"	85-322	-----
"Universities Report Research Equipment Shortages Are Most Severe in the Physical Sciences and Engineering"	85-320	-----
"Federal Emphasis on Defense is Major Factor in 1983 Increase in Industrial R&D Performance"	85-318	-----
"Federal Academic R&D Funds Continue Strong Growth Through 1985"	85-314	-----

S/E Personnel

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"Graduate S/E Enrollment Shows Smallest Increase Since 1977"	86-304	-----
"One-half of U.S. Firms Employ Foreign Scientists and Engineers"	85-336	-----
"Science and Engineering (S/E) Graduates Find Increasing Opportunities for Employment in S/E Occupations"	85-334	-----
"Scientific and Technical Employment in Manufacturing Reaches 1.5 Million in 1985"	85-330	-----
"All Fields Share in 3% Growth in Academic S/E Employment"	85-317	-----
"Shortages Increase for Engineering Personnel in Industry"	85-309	-----
"Ph. D. Scientists and Engineers Shift to Industrial Employment and Related Activities"	85-301	-----

Detailed Statistical Tables

S/E Personnel

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Reports

R&D Funds

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A Comparative Analysis of Information on National Industrial R&D Expenditures	85-311	-----

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Projected Response of the Science, Engineering, and Technical Labor Market to Defense and Nondefense Needs: 1982-87	84-304	-----

Composite

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Science and Engineering Personnel: A National Overview	85-302	-----
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